William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXVIII—No. 1

January, 1912

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXVIII—No. 1

JANUARY, 1912

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS

NEW YORK 1912

American Society of Civil Engineers

OFFICERS FOR 1912

President, JOHN A. OCKERSON

Vice-Presidents

Term expires January, 1913:	*Term expires January, 1914:*
ALFRED P. BOLLER	CHARLES S. CHURCHILL
CHARLES L. STROBEL	CHARLES D. MARX

Secretary, CHARLES WARREN HUNT

Treasurer, JOSEPH M. KNAP

Directors

Term expires January, 1913:	*Term expires January, 1914:*	*Term expires January, 1915:*
WILLIAM E. BELKNAP	GEORGE C. CLARKE	LINCOLN BUSH
HORACE LOOMIS	CHARLES W. STANIFORD	T. KENNARD THOMSON
GEORGE A. KIMBALL	JONATHAN P. SNOW	EMIL GERBER
PERCIVAL ROBERTS, JR.	ROBERT RIDGWAY	WILLIAM CAIN
CHARLES F. LOWETH	LEONARD W. RUNDLETT	E. C. LEWIS
ARTHUR DEWINT FOOTE	WILLIAM H. COURTENAY	W. A. CATTELL

Assistant Secretary, T. J. McMINN

Standing Committees

(THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES)

On Finance:	*On Publications:*	*On Library:*
HORACE LOOMIS	WILLIAM E. BELKNAP	ALFRED P. BOLLER
GEORGE A. KIMBALL	ROBERT RIDGWAY	CHARLES D. MARX
CHARLES W. STANIFORD	CHARLES S. CHURCHILL	EMIL GERBER
PERCIVAL ROBERTS, JR.	CHARLES L. STROBEL	CHARLES F. LOWETH
LINCOLN BUSH	JONATHAN P. SNOW	CHAS. WARREN HUNT

Special Committees

ON UNIFORM TESTS OF CEMENT: George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON CONCRETE AND REINFORCED CONCRETE: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

ON ENGINEERING EDUCATION: Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead.

ON STEEL COLUMNS AND STRUTS: Austin L. Bowman, Alfred P. Boller, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.................5913 Columbus.
CABLE ADDRESS.................."Ceas, New York."

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

December 20th, 1911.—The meeting was called to order at 8.30 P. M.; Director S. C. Thompson in the chair; Chas. Warren Hunt, Secretary; and present, also, 188 members and 19 guests.

A paper by M. M. O'Shaughnessy, M. Am. Soc. C. E., entitled "Construction of the Morena Rock Fill Dam, San Diego County, California," was presented by R. J. McClelland, Esq., and illustrated with lantern slides. Communications on the subject from Messrs. George L. Dillman, George F. Maddock, J. D. Galloway, and H. Hawgood, were read by the Secretary.

A paper on "The Halligan Dam: A Reinforced Masonry Structure," by G. N. Houston, M. Am. Soc. C. E., was read by title, and communications on the subject from Messrs. Lars R. Jorgensen and S. G. Swigart were presented by the Secretary, who also presented by

title communications from Messrs. Maurice G. Parsons and Charles B. Buerger.

A paper by C. L. Harrison, M. Am. Soc. C. E., entitled "Provision for Uplift and Ice Pressure in Designing Masonry Dams," was read by title. Communications on the subject from Messrs. G. M. Braune, Allen Hazen, and Charles E. Waddell, were read by the Secretary. Communications from Messrs. Edward Godfrey and C. A. Mees, were presented by title only, because of their length and the lateness of the hour. The paper was discussed orally by Messrs. E. Wegmann, Rudolph Hering, C. E. Gregory, O. L. Brodie, T. Kennard Thomson, M. G. Barnes, and C. L. Harrison.

The Secretary announced the following deaths:

George Davidson, elected Honorary Member May 5th, 1897; died December 2d, 1911.

Thomas King Sweesy, elected Junior August 31st, 1909; died September 2d, 1911.

The Secretary announced the more important features of the Programme for the Fifty-Ninth Annual Meeting.

Adjourned.

January 3d, 1912.—The meeting was called to order at 8.30 P. M.; President Endicott in the chair; Chas. Warren Hunt, Secretary; and present, also, 108 members and 7 guests.

The minutes of the meetings of November 15th and December 6th, 1911, were approved as printed in *Proceedings* for December, 1911.

A paper by Henry C. Ripley, M. Am. Soc. C. E., entitled "How to Build a Stone Jetty on a Sand Bottom in the Open Sea," was presented by the Secretary, who also read communications on the subject from Messrs. John Taylor, Lewis M. Haupt, Morton L. Tower, and Frederic V. Abbot. The paper was discussed orally by T. Kennard Thomson, M. Am. Soc. C. E.

The Secretary announced the election of the following candidates on January 2d, 1912:

As Members

Thomas Allen Appleton, Beverly, Mass.
James Clark Harding, New York City
Thomas Richard Hasley, Marquette, Mich.
Robert Howes, Seattle, Wash.
Hugh Burritt Muckleston, Calgary, Alta., Canada
Maury Nicholson, Birmingham, Ala.
William Savage Turner, Portland, Ore.

As Associate Members

Robert Edmund Andrews, Bay City, Mich.
Charles Dwight Avery, Cheyenne, Wyo.
Charles Terrell Bartlett, San Antonio, Tex.
Arthur Lee Bobbs, San Francisco, Cal.
Perry Elmer Borchers, Phœnix, Ariz.
Edward Rose Bowen, Los Angeles, Cal.
George Rowell Brown, Pittsfield, Mass.
John Henry Byrd, Kansas City, Mo.
Albert Aeneas Casani, New York City
Arthur Watson Conner, Delmar, N. Y.
William Earle Cory, Boise, Idaho
James Henry Gallivan, Poughkeepsie, N. Y.
Sylvan Earle Ganser, Boston, Mass.
Walter Nickerson Hill, St. Ignatius, Mont.
Nicholas Hanson Holmes, Hamilton, Ont., Canada
John Jay Lafayette Houston, Jamaica, N. Y.
Joseph Warren Jones, St. Louis, Mo.
William Murray Kerlinger, Berkeley, Cal.
Edgar Albert Kingsley, Little Rock, Ark.
Albert Robert Klein, Springfield, Mass.
Alfred Julius Krafft, San Francisco, Cal.
Louis Gustave Krause, Ventnor City, N. J.
Robert Walker Lemen, Oruro, Bolivia
John Ovington Lewis, Brooklyn, N. Y.
William Arthur O'Brien, Cape Girardeau, Mo.
Tom William Osgood, Medford, Ore.
Harold Tapley Pease, Deer Park, Wash.
George Gordon Pollock, Sacramento, Cal.
Henry Alexis d'Origny Saurbrey, Plainfield, N. J.
Harry Sidenius, Bassano, Alta., Canada
Robert Davis Snodgrass, Detroit, Mich.
Rex Cameron Starr, Sumner, Wash.
Frank Ernest Sterns, Culebra, Canal Zone, Panama
Jerome Branch Stocking, Hollister, Idaho
Julian Willis Stromberg, Chicago, Ill.
Clifford Albion Tinker, Westfield, Mass.
William Israel Tompkins, Massillon, Ohio
Bertrand Hinman Wait, New York City

As Juniors

Raymond Wentworth Brooks, Hartford, Iowa
Howard Thompson Critchlow, Culebra, Canal Zone, Panama
Edouard Jean Bernard de Mey, Cincinnati, Ohio

George Ray Edwards, Port Townsend, Wash.
Claes Theodore Ekman, St. Anthony Park, Minn.
Arthur Ludwig Enger, Brooklyn, N. Y.
Philip Augustus Franklin, Seattle, Wash.
George Corliss Illingworth, Albany, N. Y.
Theodore Sedgwick Johnson, Granville, Ohio
Albert Carl Kaestner, New York City
Caesar Massei, Roanoke, Va.
Garner Wakefield Miller, Memphis, Tenn.
John Posey Mudd, Philadelphia, Pa.
Alfred Rheinstein, New York City
Roger Cushing Rice, San Francisco, Cal.
Irving Rossi, Jersey City, N. J.
George Carter Stone, Dorchester, Mass.
James Arthur Thompson, New York City
Myron William Turner, Farnham, Que., Canada
Edward Hazzard West, Louisville, Ky.

The Secretary announced the transfer of the following candidates on January 2d, 1912:

From Associate Member to Member

Richard William Carter, Marathon, Fla.
Jacob Anthony Harman, Peoria, Ill.
Frederick Percival Kafka, New York City
Charles Austin Wentworth, Philadelphia, Pa.

From Junior to Associate Member

Harry Bortin, Omaha, Nebr.
John Earl Cunningham, Boston, Mass.
Frederick Clayton Harper, Chicago, Ill.
William Otto Lichtner, Newton Highlands, Mass.
Harold Scott Loughran, New Rochelle, N. Y.
William Edmund Price, Oklahoma City, Okla.
William Wolcott Tefft, Grand Rapids, Mo.
James Brackett Van Vleck, St. Louis, Mo.

The Secretary announced the death of:

Nathan Jackson Gibbs, elected Associate Member, May 2d, 1911; died December 27th, 1911.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

January 2d, 1912.—President Endicott in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bates, Belknap, Bensel, Boller, Kimball, Ridgway, Snow, Stearns, and Thompson.

The following resolution was passed:

"*Resolved:* That as soon as possible during the year $10 000 be paid on the principal of the mortgage debt of the Society, and further that $20 000 be set aside for the purchase of bonds to be added to the Reserve Fund, under the same conditions and rules as per the last action of the Board in this matter."

The Annual Report of the Board of Direction was adopted for presentation to the Annual Meeting.

A resolution relating to payment for collations for the regular semi-monthly meetings of the Society for presentation to the Annual Meeting was adopted.

The following letter, addressed to the President, was received:

"Dear Admiral Endicott:

"Owing to the formation of the New York Railways Co., I find that my duties and responsibilities will be very largely increased, so that I am compelled to ask the Board of Direction to accept my resignation as a Director, same to take effect immediately.

"Will you kindly convey to the other members of the Board my appreciation of the privilege of acting with them during the past year and my regret at having to sever my connection with the Board.

"Yours very truly,

"H. G. Stott."

The resignation of Henry G. Stott as a Director of the Society was accepted, and the Secretary was instructed to express the regret of the Board that it was necessary for him to withdraw.

The vacancy in the office of Director representing District No. 1, for the unexpired term, to which Henry G. Stott was elected, was filled by the election of Charles W. Staniford of New York City.

The Board approved the following amendment to the Constitution of the San Francisco Association of Members of the Society:

"Section 1 of Article III of the Constitution relative to dues is hereby amended to read as follows:

"Section 1. The annual dues payable by all members shall not be more than $5, payable annually in advance on the first day of January, and any member whose dues are more than one year in arrears shall cease to be a member of this Association."

A report from the Committee to Recommend the Award of Prizes for the year ending with *Transactions* for July, 1911, was received,

and the prizes were awarded in accordance with the recommendations of that Committee as follows:

The Norman Medal to Paper No. 1165, "The New York Tunnel Extension of the Pennsylvania Railroad. Station Construction, Road, Track, Yard Equipment, Electric Traction and Locomotives," by George Gibbs, M. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 1155, "The New York Tunnel Extension of the Pennsylvania Railroad. The North River Tunnels," by B. H. M. Hewett and W. L. Brown, Members, Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 1173, "A Concrete Water Tower," by A. Kempkey, Jr., Jun. Am. Soc. C. E.*

Action was taken in regard to members in arrears for dues.

The resignations of 4 Members, 12 Associate Members, 4 Associates, and 9 Juniors were accepted.

Ballots for membership were canvassed, resulting in the election of 7 Members, 38 Associate Members, and 20 Juniors, and the transfer of 8 Juniors to the grade of Associate Member.

Four Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

* Now Assoc. M. Am. Soc. C. E.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

February 7th, 1912.—8.30 P. M.—A regular business meeting will be held, and a paper by Frederick C. Noble, M. Am. Soc. C. E., entitled "Notes on a Tunnel Survey," will be presented for discussion.

This paper was printed in *Proceedings* for December, 1911.

February 21st, 1912.—8.30 P. M.—At this meeting a paper by B. F. Cresson, Jr., M. Am. Soc. C. E., entitled "The Problem of the Lower West Side Manhattan Water-Front of the Port of New York," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

March 6th, 1912.—8.30 P. M.—This will be a regular business meeting. A paper by N. B. Sweitzer, Assoc. M. Am. Soc. C. E., entitled "Retracement-Resurveys—Court Decisions and Field Procedure," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

CHANGES IN METHOD OF PUBLISHING TRANSACTIONS

The *Transactions,* which during the past three years have been issued in four volumes per year, will in 1912 and thereafter be published in one annual volume.

This important change has been decided on by the Board of Direction because it will overcome, or mitigate to a considerable extent, the many disadvantages connected with the old system, as detailed in the report of the Secretary to the Board dated June 6th, 1911 (*Proceedings* for August, 1911, p. 319).

The yearly volumes will be printed on thin "India" or "Bible" paper, and will contain approximately as much material as four of the volumes hitherto published. Its thickness will be somewhat less than half that of the four volumes combined.

To non-members the subscription for this single volume, if entered before February 1st, will be the same as heretofore for the four volumes: $12, with a discount to libraries, book dealers, etc., of 25 per cent.

To members the cost of binding will be $1.50 per volume for half morocco and 75 cents for cloth, thus effecting a saving of from $1.25 to $2.50 per annum to each member who has his *Transactions* bound.

It is expected that the volume for 1912 (Vol. LXXV) will be issued toward the close of the year.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to

**Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

December 15th, 1911.—The Seventh Annual Meeting was called to order; President Derleth in the chair; E. T. Thurston, Jr., Secretary; and present, also, 75 members and guests.

The Secretary reported that the average attendance at meetings during the year was 67, as compared with 42 during 1910; and an increase in membership of 28, making the present membership 146.

The Treasurer reported receipts to December 15th, 1911, of $782.33; disbursements, $302.00; and a balance on hand of $2 682.02.

C. E. Grunsky, M. Am. Soc. C. E., was elected President, and C. H. Snyder, M. Am. Soc. C. E., Vice-President.

Mr. A. L. Bobbs presented a paper on the "Structural Design of the Main Towers and Campanile of the Saint Ignatius Church," illustrating his remarks with stereopticon views, and the paper was generally discussed.

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Gavin N. Houston, M. Am. Soc. C. E., 409 Equitable Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

November 11th, 1911.—The meeting was called to order; President Anderson in the chair; G. N. Houston, Secretary; and present, also, 10 members and 6 guests.

A discussion on the subject of Good Roads was opened by J. E. Maloney, M. Am. Soc. C. E., Engineer for the State Highway Commission, who illustrated his remarks with stereopticon views. The subject was further discussed by Messrs. C. P. Allen, Tully, and others.

Adjourned.

December 16th, 1911.—The meeting was called to order; President Anderson in the chair; G. N. Houston, Secretary; and present, also, 13 members and 6 guests.

The subject for discussion was "The Futility of Technical Schools," as outlined in a pamphlet by Mr. R. T. Crane, of Chicago, Ill., the following members and guests taking part: Messrs. House, Knapp, Ketchum, Bartlett, Crocker, Ridgway, Thomas, Anderson, and Houston.

Adjourned.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all Meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburg, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1911.

In compliance with the Constitution, the Board of Direction presents its report for the year ending December 31st, 1911.

MEMBERSHIP.

The changes in membership are shown in the following table:

	Jan. 1st, 1911.			Jan. 1st, 1912.			Losses.				Additions.		Total.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.	Increase.
Honorary Members...	.....	8	8	.....	8	8	....	..	..	1	1	....	1	1	....
Corresponding " ...	.....	2	2	.....	2	2	....	..	..	..	....	....	....	....	....
Members.............	597	2 170	2 767	623	2 305	2 928	1	6	2	31	*83	118	40	201	161
Associate Members...	454	1 630	2 084	497	1 889	2 386	81	18	4	14	†93	§326	117	419	302
Associates...........	78	92	170	80	98	178	5	4	1	..	‡2	16	10	18	8
Juniors...............	153	592	745	169	634	803	92	18	17	7	....	192	134	192	58
Fellows...............	6	15	21	6	15	21	....	..	..	..	....	....	....	....	....
Totals...........	1 288	4 509	5 797	1 375	4 951	6 326	179	46	24	53	179	652	302	831	529

*81 Associate Members and 2 Associates.
† 3 Associates and 90 Juniors.
‡ 2 Juniors.
§ 1 Reinstatement.

The net increase for the year, 529, is the largest yearly addition to the membership in the history of the Society. A diagram showing the growth of the Society since 1871, when its membership was somewhat less than 250, is appended to this report, and shows that during the last 11 years the average yearly rate of increase has been 9½ per cent.

The number of applications received during 1911 was 925: 712 for admission, and 213 for transfer.

The losses by death reported during the year number 53, and are as follows:

Honorary Members (1): George Davidson.

Members (31): John Bond Atkinson, George Joseph Bell, Roswell Emmons Briggs, George Bowers Caldwell, James Christie, Francis Collingwood, Benjamin Douglas, Charles Morton Emmons, William Bion Ewing, John Thomas Fanning, Charles Arthur Hague, John Franklin Hinckley, Horace Joseph Howe, Edward Marion Kenly, Charles Cyrus King, Alfred Courtney Lewerenz, Harvey Childs Lowrie, Benjamin Franklin Mackall, Wallace McGrath, John Joseph McLaughlin,

Charles Arthur Matcham, Edward P. North, Henry Pierce, Evelyn Pierrepont Roberts, John Edward Schwitzer, Alfred Francis Sears, Walter Herbert Sears, John Wright Seaver, James Smith, William Dana Taylor, Charles Widney Wood.

Associate Members (14): Nathan Jackson Gibbs, Joseph Canby Hadsall, Louis Edwin Hawes, Irving Hawkins, Edwin Merritt Holmes, Albert Victor Kellogg, George William Lee, Javier Diaz Lombardo, Ralph Barton Manter, Homer Austin Patch, Takejiro Shima, Thomas William Rostad Teigen, Fridthjov Lauritz Martin Tönnesen, Willis Tubbs Turner.

Juniors (7): Joseph James Ferrier, Joseph Heckart Frazer, Richard Hazen, Walter Edward Lydston, Thomas King Sweesy, Samuel Dale Watkins, Alexander Ilich Wolkowyski.

LIBRARY.

The total contents of the Library and the increase during the year, are shown in the following statement:

	Total Contents.	Increase during 1911.
Bound volumes....................	20 625	1 072
Unbound volumes..................	39 717	1 732
Specifications	7 017	248
Maps, photographs and drawings....	4 426	113
Total	71 785	3 165

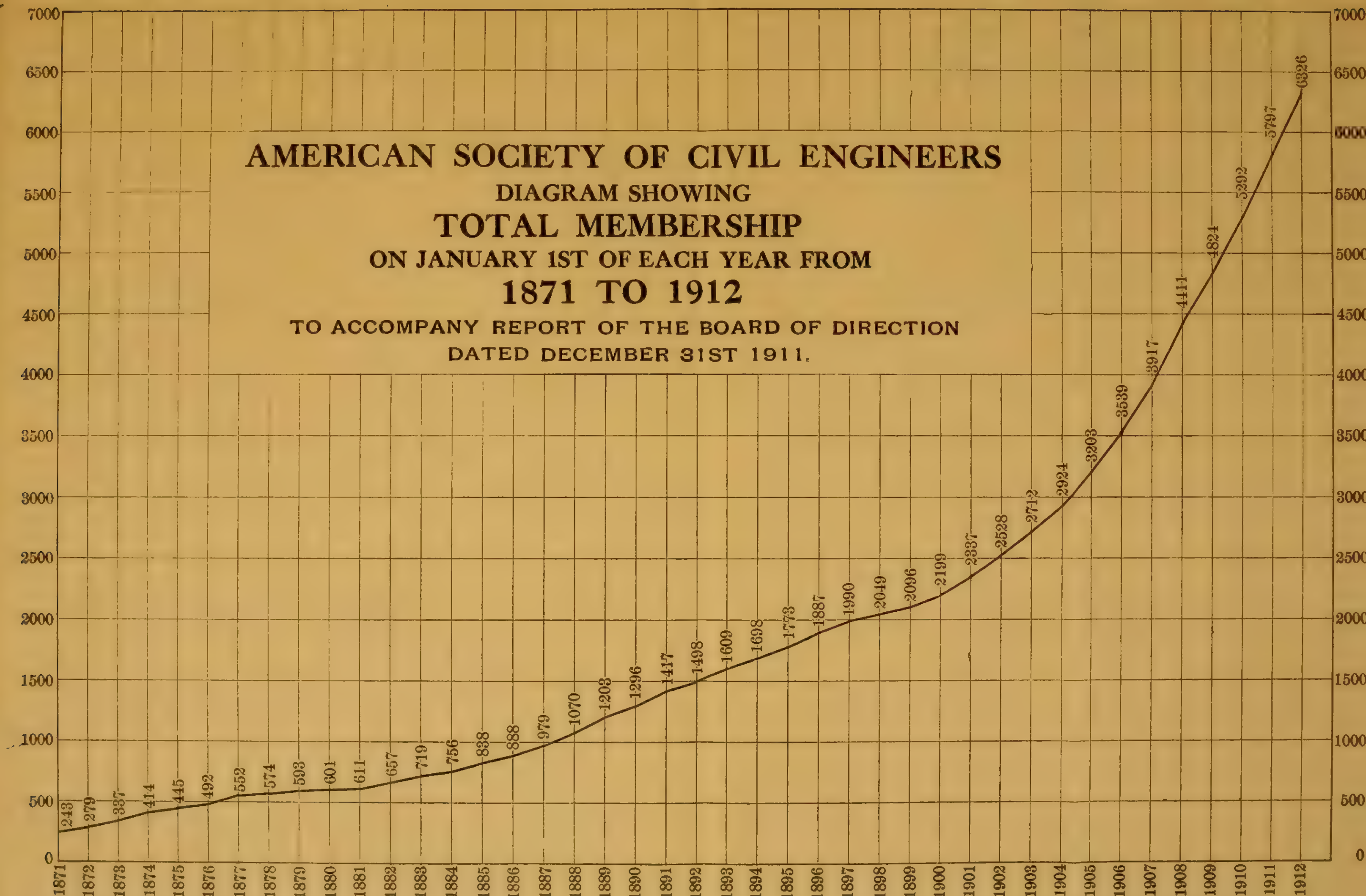
Of these, 920 were donations received in answer to special requests; 78 were donations from publishers; 1 986 were donations received in regular course, and 181 were purchased.

The value of accessions to the Library during the year is as follows, each accession having been valued separately as received:

Donations and exchanges (estimated value)..	$2 315.03
181 Volumes purchased (cost).............	710.73
Binding 335 volumes.......................	358.52
Total	$3 384.28

The following amounts have been expended upon the Library during the year:

Purchases, subscriptions, and binding........	$1 069.25
Fixtures, supplies, and sundries............	235.14
Total	$1 304.39


AMERICAN SOCIETY OF CIVIL ENGINEERS
DIAGRAM SHOWING
TOTAL MEMBERSHIP
ON JANUARY 1ST OF EACH YEAR FROM
1871 TO 1912
TO ACCOMPANY REPORT OF THE BOARD OF DIRECTION
DATED DECEMBER 31ST 1911.
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
243
279
337
414
445
492
552
574
593
601
611
657
719
756
838
888
979
1070
1203
1296
1417
1498
1609
1698
1773
1887
1990
2049
2096
2199
2337
2528
2712
2924
3203
3539
3917
4411
4824
5292
5797
6326

The total attendance in the Reading Room and Library during the year was 4 232.

During the year 67 new bibliographies (containing 2 162 separate references) have been made, copies of 357 searches made in previous years (285 of which were made for a correspondent in Japan) have been furnished, 10 of these having been brought up to date. The total cost of this work, $1 335.47, has been charged to those for whom it was undertaken.

In previous reports of the Board, statistics of the Library similar to those above have been given, but it is believed that few members realize the amount of work and expense involved in the classification, indexing, and maintenance of a library and reading room. The classification and indexing of our Library was begun in March, 1898, and occupied about two years.

On December 31st, 1900, 30 201 accessions had been classified and catalogued. During the succeeding eleven years 41 196 additions have been made, an average of 3 745 per annum, or more than 12 for each working day. Two volumes of a Catalogue of the Library have been issued, the first in 1900, and the second in 1903.

The card index now contains about 77 000 cards.

In addition to this work the Reading Room is open thirteen hours every day (except Sundays and three of the more prominent holidays), during which time the attendance of one, and at times two library assistants is always necessary. Added to this is the work of making searches for members, which has grown greatly since its inception, and apparently has been found helpful to all those who have taken advantage of the opportunity to secure bibliographies on special subjects in which they are interested. The list of articles in current technical literature, which is published in *Proceedings,* entails the monthly examination of more than one hundred periodicals, and this work is also done by the Library force.

In order to keep the Library up to date, all lists issued by technical publishers, and all book notices in technical journals, are examined as soon as issued, and letters written with a view of securing all engineering books, either by gift or purchase. This, together with acknowledgments of donations, etc., produces a voluminous correspondence, which, added to the assistance given to those who consult the Library, to the mending and care of books and periodicals, to their preparation for binding (about 400 volumes are bound annually), to the care of the stack room, and to many other details which it is impossible to enumerate here, calls for a considerable force of competent persons, and necessitates an amount of painstaking labor which it is believed is not realized by any one not familiar with such work.

PUBLICATIONS.

During the year, ten numbers of *Proceedings* have been issued regularly, and four volumes of *Transactions*. One of these volumes (LXIX) is the belated second volume of the Pennsylvania Railroad Papers, which it was not possible to publish in 1910, due to the fact that one of the papers was not received until the Spring of 1911.

In *Proceedings* the list of references to current engineering literature has been continued, and has covered 134 pages and contained 5 336 classified references to 103 periodicals.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 155 285 copies, the cost of which to the Society, for paper and press work only, has been $23 598.01.

During the year, 15 220 volumes of *Transactions* have been bound for members and others in standard half-morocco and cloth bindings.

SUMMARY OF PUBLICATIONS FOR 1911.

	Issues.	Average Edition.	Total Pages.	Plates.	Cuts.
*Transactions** (volumes).........	4	6 450	2 067	235	274
Proceedings (monthly numbers)...	10	6 560	2 030	162	177
Constitution and List of Members	1	7 000	254	...	1
Totals.............	15	....	4 351	397	452

The cost of publications has been:

For Paper, Printing, etc., *Transactions* and *Proceedings*...	$25 982.36
For Plates and Cuts..................................	2 332.45
For Boxes, Mailing Lists, Copyright, and Sundry Expenses.	1 344.18
For 8 900 Extra Copies of Papers and Memoirs...........	1 054.38
For List of Members..................................	1 597.43
Total	$32 310.80
Deduct amount received from sale of publications.........	4 437.92
Net expenditure for publications for 1911..........	$27 872.88

The last of the quarterly volumes for 1911 has not yet been issued, owing to the lack of material to make up the volume, due to the impossibility of closing certain discussions. It is expected that this volume will be issued early in 1912. This will be the last of the quarterly volumes.

A new method of publication will go into effect in 1912. It has been described fully in *Proceedings,* but as it may have escaped the attention of some members, is briefly restated here.

*LXIX, LXXI, LXXII, LXXIII.

Proceedings will be issued as before, monthly, except that there will be no issue for the months of June and July, and in future there will be in each Number a brief index, or table of contents, covering the papers and discussions which are appearing serially. It is expected that the written discussion of papers can, under this system, be held open for a longer period, and that all discussion will appear first in *Proceedings,* before its collation and subsequent issue with the original paper in the yearly volume of *Transactions*. This will enable members to keep in touch more promptly with all technical matter issued by the Society than has been possible heretofore, and at the same time, each volume of *Transactions* (which is the permanent record) will contain quite as much material as four of the quarterly volumes heretofore published, and will occupy less than half the shelf room. The saving to each member who has these volumes bound will also be considerable. These volumes of *Transactions* will be printed on "Bible" or "India" paper of the best quality obtainable, and it is believed the change will in many ways be a material advance.

MEETINGS.

During the year 26 meetings have been held, as follows: At the Annual Meeting, 2; at the Annual Convention, 3; and 21 other meeting held at the Society House.

At these meetings there were presented 25 formal papers, 7 of which were illustrated with lantern slides. There were also 7 papers published in the *Proceedings* which were not presented for discussion at any meeting of the Society. The number of members and others who took part in the preparation or discussion of these papers was 222.

The Forty-third Annual Convention was held at Chattanooga, Tenn.

The total attendance at the 26 meetings held was about 3 891. The registered attendance at the Annual Meeting was 782, and at the Annual Convention 87 (includes members only), but there were many members and guests present at all these meetings who failed to register.

MEDALS AND PRIZES.

For the year ending with the month of July, 1910, prizes were awarded as follows:

The Norman Medal to C. E. Grunsky, M. Am. Soc. C. E., for his paper entitled "The Sewer System of San Francisco, and a Solution of the Storm-Water Flow Problem."

The Thomas Fitch Rowland Prize to John H. Gregory, M. Am. Soc. C. E., for his paper entitled "The Improved Water and Sewage Works of Columbus, Ohio."

No award of the Collingwood Prize for Juniors was made, as no paper by a Junior was published in the four volumes of *Transactions* which appeared during the year ending July, 1910.

FINANCES.

During the year $10 000 was paid on the principal of the Mortgage on the Society Property, reducing this debt to $125 000. An addition of $20 000 was also made to the Reserve Fund established last year, and the Society now has a Reserve Fund of $37 000, invested in non-taxable bonds of the City of New York, which yields somewhat more than 4% interest. The Board has ordered that $10 000 be paid on the principal of the mortgage early in 1912, and that $20 000 be added to the Reserve Fund.

The attention of members is invited to the Secretary's statement of receipts and disbursements, and to the general balance sheet which accompanies it, in which the financial condition of the Society is shown.

The reports of the Secretary and Treasurer are appended.

By order of the Board of Direction,

Chas. Warren Hunt,

Secretary.

January 2d, 1912.

GENERAL BALANCE SHEET, DECEMBER 31st, 1911.

Accompanying the Report of the Secretary.

Assets.

Three Lots (Actual cost, $189 632.11) (Estimated value)		$375 000.00
Society Building (cost)		170 955.59
Furniture (cost)		19 780.57
Publications on hand (inventoried cost)		23 598.01
New York City Non-Taxable Bonds (cost)		40 225.00
Library: Cash expended for books, etc.	$15 951.96	
Donations (estimated)	60 384.00	76 335.96
Due from Members		8 876.58
Due from Non-Members		181.63
Cash		46 363.95
		$761 317.29

Liabilities.

Dues for 1912 paid in advance	$25 889.99
Mortgage Debt and Loan	125 000.00
Funds invested in Society House, Lots and Library*	26 940.78
Herbert Stewart Library Fund	1 997.50
Gen. Joseph G. Swift Library Fund	998.75
Surplus (including Reserve Fund of $37 228.75)	580 490.27
	$761 317.29

We have examined the books and accounts of the American Society of Civil Engineers, for the year ended December 31, 1911, and certify that the foregoing Balance Sheet is in accordance therewith, and, in our opinion, correctly states the condition of the Society's affairs, as shown by the books.

79 Wall Street, New York.
January 9, 1912.

Marwick, Mitchell, Peat, & Co.,
Chartered Accountants.

* Compounding Dues Fund, $10 680.00; Norman Medal Fund, $1 000.00; Rowland Prize Fund, $1 222.50; Collingwood Prize Fund, $1 000.00; Fellowship Fund, $13 038.28

REPORT OF THE SECRETARY FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Receipts 31st, 1911. I also append a general balance sheet showing the condition

Receipts.

Balance on hand December 31st, 1910, in Bank, Trust Company, and in hands of Treasurer....		$42 492.83
Entrance Fees..............................	$15 680.00	
Current Dues..............................	69 934.50	
Past Dues..............................	2 678.95	
Advance Dues..............................	25 889.99	
Certificates of Membership..................	704.43	
Badges	2 976.38	
Sales of Publications....................	4 437.92	
Library	1 323.06	
Annual Meeting..........................	1 371.40	
Binding	9 716.86	
Interest	2 601.42	
Miscellaneous	254.72	
		137 569.63
		$180 062.46

YEAR ENDING DECEMBER 31st, 1911.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

and Disbursements for the fiscal year of the Society, ending December
of the affairs of the Society.

Respectfully submitted,
CHAS. WARREN HUNT,
Secretary.

DISBURSEMENTS.

Salaries of Officers	$12 800.00	
Mileage of Directors	1 548.34	
Clerical Help	19 323.98	
Caretaking	1 911.36	
Publications	32 310.80	
Postage	7 138.51	
General Printing and Stationery	3 350.87	
Library	1 069.25	
Library Maintenance	235.14	
Badges	2 129.75	
Certificates of Membership	502.91	
Binding	8 014.39	
Prizes	118.20	
Convention	740.90	
Annual Meeting	2 205.41	
Maintenance of House	1 052.94	
Heat, Light, and Water	1 274.40	
Furniture	532.93	
Work of Committees	338.32	
Interest and Insurance	5 228.92	
Current Business	1 315.82	
Petty Expenses	226.01	
Members' Accounts	79.36	
Bond and Mortgage (Payment on Principal)	10 000.00	
Reserve Fund	20 250.00	
		$133 698.51
Balance on hand December 31st, 1911:		
In Union Trust Company	$9 668.60	
In Garfield National Bank	35 195.35	
In hands of Treasurer	1 500.00	
		46 363.95
		$180 062.46

REPORT OF THE TREASURER.

In compliance with the provisions of the Constitution, I have the honor to present the following report for the year ending December 31st, 1911:

Balance on hand December 31st, 1910		$42 492.83
Receipts from current sources, January 1st to December 31st, 1911		137 569.63
Payment of Audited Vouchers for Current Business, January 1st to December 31st, 1911	$103 448.51	
Payment on principal of bond and mortgage	10 000.00	
Purchase of bonds, Reserve Fund	20 250.00	
Balance on hand December 31st, 1911:		
In Union Trust Company $9 668.60		
In Garfield National Bank 35 195.35		
In hands of the Treasurer 1 500.00	46 363.95	
	$180 062.46	$180 062.46

Respectfully submitted,

Jos. M. Knap,
Treasurer.

New York, January 2d, 1912.

ACCESSIONS TO THE LIBRARY

(From December 9th, 1911, to January 4th, 1912)

DONATIONS *

EXPERIMENTAL ENGINEERING.

By U. T. Holmes. Cloth, 9½ x 6 in., illus., 311 pp. Annapolis, Md., The United States Naval Institute, 1911. $2.50.

On account of the new matter at hand and the many changes made necessary by reason of it, the author states that, after attempting to revise his "Notes on Experimental Engineering," published in 1907, he found it necessary to rewrite the whole book. The text treats of the instruments and methods used in the collection of engineering data, and includes the testing of materials and appliances used in engineering work—the materials to determine their strength or suitability for the purpose required, and the appliances to determine the amount of work done on them, or by them, and their efficiency. The work is also intended to familiarize the student with the various instruments used in experimental engineering, as well as with the methods of calibrating and using them. At the end of the book, the author has given a series of questions on the subject-matter in each chapter. The Contents are: Introduction; Instruments for Computing Experimental Data; Instruments for Recording Experimental Data; Measurement of the Quality of Steam; Measurement of the Rate of Flow of Water; Measurement of the Rate of Flow of Air and Steam; Measurement of Power; Testing Materials of Construction; Engine Lubrication; The Selection and Testing of Fuel; Flue Gas Analysis; Index.

THE HOUSE FLY—DISEASE CARRIER.

An Account of Its Dangerous Activities and of the Means of Destroying it. By L. O. Howard. Cloth, 8¼ x 5½ in., illus., 19 + 312 pp. New York, Frederick A. Stokes Company, 1911. $1.60.

This book, it is stated, is not intended to be a scientific monograph on the house-fly in connection with its disease-carrying possibilities, but is simply an attempt to give in a condensed and convenient form that which is known in relation to the subject. The Contents are: Zoological Position, Life History, and Habits; The Natural Enemies of the Typhoid Fly; The Carriage of Disease by Flies; Remedies and Preventive Measures; Other Flies Frequenting Houses; Biographical List; Appendix I, Flies Frequenting Human Dejecta and Those Found in Kitchens; Appendix II, On Some Flies Reared from Cow Manure; Appendix III, Regulations of the Health Department of the District of Columbia Relating to House Flies; Appendix IV, Directions for Building a Sanitary Privy; Appendix V, A Simple Apparatus for Use in the Safe Disposal of Night-Soil.

TECHNOLOGY AND INDUSTRIAL EFFICIENCY.

A Series of Papers Presented at the Congress of Technology, Opened in Boston, Mass., April 10th, 1911, in Celebration of the Fiftieth Anniversary of the Granting of a Charter to the Massachusetts Institute of Technology. Cloth, 9¼ x 6¼ in., illus., 9 + 486 pp. New York and London, McGraw-Hill Book Company, 1911. $3.00.

As stated in the secondary title, this volume contains a series of papers by the Alumni of the Massachusetts Institute of Technology, and by members of its Faculty, presented at a Congress of Technology held in Boston, Mass., in 1911, to celebrate the Fiftieth Anniversary of its founding. Each problem, it is stated, is discussed by men who know the subject and who have had practical experience in it, the guiding idea throughout being the gain in efficiency which comes from the application of scientific methods to the treatment of the practical problems of the day. The Chapter headings are: Section A, Scientific Investigation and Control of Industrial Processes; Section B, Technological Education in Its Relations to Industrial Development; Section C, Administration and Management; Section D, Recent Industrial Development; Section E, Public Health and Sanitation; Section F, Architecture.

* Unless otherwise specified, books in this list have been donated by the publisher.

RETAINING-WALLS FOR EARTH

Including the Theory of Earth-Pressure as Developed from the Ellipse of Stress, with a Short Treatise on Foundations, Illustrated with Examples from Practice. By Malverd A. Howe, M. Am. Soc. C. E. Fifth Edition, Revised and Enlarged. Cloth, 7½ x 5 in., illus., 12 + 181 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1911. $1.25. (Donated by the Author.)

The demonstrations used in this book are stated to be based on the theory advanced by Professor Rankine in 1858, and to be presented in a manner easily followed by those who have only a knowledge of algebra, geometry, and trigonometry, the work having been simplified as much as possible whenever calculus has been resorted to. For convenience the author first discusses the theory of his subject, which discussion is followed by formulas and by numerous examples illustrating their application. The values of the various coefficients have been computed, it is stated, with a Thacher calculating instrument and checked by means of diagrams. In this, the fifth edition, it is stated that a number of changes have been made. The formulas for offsets in foundations have been revised, and Appendix A, which contains a discussion on reinforced concrete retaining walls, has been rewritten to conform with standard momenclature and formulas. Numerous profiles of walls actually constructed are also shown in Appendices A and B. The Contents are: Theory of Earth-Pressure; Formulas for Earth-Pressure; Stability of Trapezoidal Walls; Formulas for Trapezoidal and Triangular Walls; Foundations for Walls Retaining Earth; Examples; Foundations; Foundations Under Water and Deep Foundations; Types of Existing Foundations; References: Earth-Pressure and Retaining Walls; Tables: I, Weights and Crushing Strengths of Materials; II, Angles and Coefficients of Friction; III, Values of Functions *B, C, D,* and *E;* IV, Natural Sines, Cosines, Tangents, and Cotangents; Appendices: A, Reinforced Concrete Retaining Walls; B, Profiles of Gravity Walls Retaining Earth.

EXPERIMENTAL ENGINEERING AND MANUAL FOR TESTING

For Engineers and for Students in Engineering Laboratories. By Rolla C. Carpenter, and Herman Diederichs. Seventh Edition, Rewritten and Enlarged. Cloth, 9¼ x 6¼ in., illus., 19 + 1 132 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1911. $6.00.

The first edition of this work was published in 1892. In this, the seventh edition, the subject-matter is stated to have been greatly enlarged and entirely rewritten owing to the rapid development in mechanical engineering and the numerous improvements in methods of investigation and in the apparatus used in such investigation. All obsolete or practically unnecessary matter has been omitted, it is stated, the greater part of the new matter added being due to the extended treatment given to subjects relating to gas engines and producers, steam turbines, and refrigerating and hydraulic machinery. The work is intended chiefly for use in engineering laboratories. Brief statements of the theoretical principles involved in connection with each experiment are given, with references, when necessary, to more complete demonstrations; short descriptions of the various classes of engineering apparatus or machinery, a full statement of methods of testing in nearly every department, except electrical, and of preparing reports, are also included. While dealing principally with educational methods, it is believed by the authors that the book will be found useful for reference by consulting and practising engineers, as it contains the principal standard methods for testing materials, engines, and other machinery, and an extensive series of tables for computing results, as well as descriptions of apparatus required in testing, and directions for taking data and deducing results in experimental engineering. The Chapter headings are: Introductory; Apparatus for Reduction of Experimental Data and for Accurate Measurement; Strength of Materials: General Formulæ, Testing-Machines, Methods of Testing; Measurement of Pressure; Measurement of Temperature; The Measurement of Speed; Friction, Testing of Lubricants; Measurement and Transmission of Power; Heat and the Properties of Gases and Vapors; The Measurement of Liquids, Gases and Vapors; Combustion and Fuels; Methods of Determining the Amount of Moisture in Steam; The Engine Indicator; The Indicator-Diagram; The Testing of Steam Boilers; The Testing of Steam Engines, Pumping Engines, and Locomotives; Steam Turbines; The Testing of Injectors; Gas Engines and Gas Producers; Hot-Air Engines; Air-Compressing Machinery; Mechanical Refrigeration; Hydraulic Machinery; Appendix: Tables; Index.

THE STEAM TURBINE.

The Rede Lecture, 1911. By *Sir* Charles A. Parsons. Cloth, 7½ x 5 in., illus., 57 pp. Cambridge, England, University Press, 1911. 50 cents. (Donated by G. P. Putnam's Sons.)

The author is one of the pioneers in the field of steam turbines and is an authority on the subject. In this lecture he gives a short description of some of his experimental research work in connection with the subject. This is followed by a discussion of the gradual development of the various types of steam turbines, and an explanation of the theory of action of a few distinctive types, together with a comparison of their advantages and disadvantages. For marine uses, the author discusses the demands of the propeller on the turbine designer and the phenomenon of cavitation, and gives a description of the improvements which are being made to increase still further the economy of the steam turbine as a prime mover for marine uses.

HIGHWAY ENGINEERING.

As Presented at the Second International Road Congress, Brussels, 1910. By Arthur H. Blanchard, M. Am. Soc. C. E., and Henry B. Drowne, Assoc. M. Am. Soc. C. E. Cloth, 9¼ x 6 in., 10 + 299 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1912. $2.00.

To render available to those interested in the progress of highway engineering the information relative to the construction and maintenance of roads and pavements which was presented at Brussels in 1910, is stated to be the object of this book. The first part relates to the organization of the Second International Road Congress, and contains a list of the various topics discussed, with the names of the engineers who opened the discussions and a short description of the exhibition held in connection with the Congress as well as of the excursions and receptions. Part II, the main part of the book, is devoted to the presentation of the technical discussions before the Congress. The material has been collated under headings familiar to American engineers, and the discussions follow the names of the contributors. The discussions of a given topic relative to practice in a given country, have been grouped and arranged alphabetically in each chapter. The names, titles and addresses of all contributors to a discussion are given at the beginning of each chapter, and the United States standard equivalents of foreign monetary values, weights, and measures, have been used. The Contents are: Introductory: The Congress; The Exhibition; The Excursions and Receptions. Technical Discussions: Economics of Highway Engineering; Traffic Census; Materials of Highway Engineering; Foundation and Drainage; Macadam and Gravel Roads; Dust Prevention by the Use of Palliatives; Bituminous Surfaces; Bituminous Pavements; Brick, Concrete, Stone Block and Wood Block Pavements; Trackways; Footways in Towns and Cities; Road Machinery and Tools; Garbage Removal, Cleaning and Watering; Removal of Snow and Ice; Road Signs; Pipe Systems in Roads and Streets; Tramways on Roads and Streets; Public Service Conveyances; Highway Bridges; Tires; Conclusions Adopted at the Second Congress. Appendices: I, Proceedings of the Permanent International Commission; II, Regulations of the Permanent International Association of Road Congresses; Author Index; Subject Index.

Gifts have also been received from the following:

Ackerson, J. A. 1 pam.
Am. Inst. of Elec. Engrs. 1 pam.
Am. Min. Congress. 1 vol.
Am. Ry. Assoc. 1 pam.
Am. Ry. Master Mechanics' Assoc. 1 bound vol.
Am. Soc. of Agri. Engrs. 1 vol.
Assoc. of Drainage and Levee Dists. of Illinois. 1 pam.
Brazil Ry. Co. 2 pam.
Brush, W. W. 1 pam.
Bucyrus Co., The. 1 bound vol.
Canada-Dept. of Marine and Fisheries. 1 vol.
Chemisches Laboratorium für Tonindustrie. 1 bound vol., 2 vol.
Chicago, Peoria & St. Louis Ry. Co. 1 pam.
Chicago Sanitary Dist. 3 pam.
Colorado-State R. R. Comm. 1 pam.
Colorado, Univ. of. 3 vol.
Compagnie des Chemins de Fer de l'Est. 1 pam.
Concrete Inst. 1 vol.
Cuarto Congreso Cientifico Pan-Americano. 1 vol.
Detroit Eng. Soc. 1 pam.
Dist. of Columbia-Engr. Dept. 1 vol.
East Indian Ry. Co. 1 pam.
Germany Reichseisenbahnen in Elsass-Lothringen. 1 vol.
Great Britain-Patent Office. 6 vol.
Great Indian Peninsula Ry. Co. 1 pam.

Hartford, Conn.-Comm. on the City Plan. 1 pam.
Hawaii-Board of Health. 1 pam.
Heyland, A. 1 pam.
Hinckley, H. V. 1 pam.
Illinois-State Highway Comm. 1 bound vol.
Institution of Engrs. and Shipbuilders in Scotland. 1 bound vol.
Institution of Min. and Metallurgy. 1 bound vol.
Institution of Min. Engrs. 1 pam.
Iowa-Board of R. R. Commrs. 1 bound vol.
Iowa State Coll. Eng. Soc. 1 pam.
Kansas-State Board of Health Commrs. 2 pam.
Lake Superior Min. Inst. 1 vol.
Lehigh & Hudson River Ry. Co. 1 pam.
Lippincott, J. B. 1 pam.
Madeley, J. W. 1 bound vol., 1 pam.
Manchester Steam Users Assoc. 1 pam.
Maryland-Geol. Surv. 1 pam.
Massachusetts-Bureau of Statistics. 1 bound vol., 4 pam.
Massachusetts Inst. of Technology. 1 vol.
Mercantile Press Club. 1 bound vol.
Milwaukee, Wis.-Bureau of Economy and Efficiency. 1 pam.
Minneapolis & St. Louis R. R. Co. 5 pam.
Montana State Coll. of Agri. and Mechanic Arts. 1 vol.
National Assoc. of Cotton Mfrs. 2 bound vol.
National Board of Fire Underwriters. 2 pam.
National Elec. Light Assoc. 2 bound vol.
National Employment Exchange. 1 pam.
New York-Commrs. of the State Reservation at Niagara. 1 pam.
New York State-Public Service Comm., First Dist. 1 bound vol.
New York City Record. 5 bound vol.
Ohio-Highway Dept. 1 pam.
Ohio Elec. Light Assoc. 2 bound vol.
Oklahoma-Geol. Survey. 1 vol.
Ontario, Canada-Minister of Mines. 6 pam.
Parsons, B. H. 2 pam.
Pennsylvania-Water Supply Comm. 1 bound vol.
Philadelphia, Pa.-Mayor. 3 bound vol.
Philippine Islands-Bureau of Forestry. 1 pam.
Philippine Islands-Bureau of Sci. 1 pam.
Philippine Soc. of Engrs. 2 pam.
Plymouth, England-Corporation Water-Works. 1 pam.
Porto Rico-Dept. of Health, Charities and Correction. 1 pam.
Reading, Pa.-Water Dept. 1 bound vol.
Rhode Island-Stone Bridge Comm. for Operation and Maintenance. 1 pam.
Richmond, Fredericksburg & Potomac R. R. Co. 1 pam.
San Francisco, Cal., Chamber of Commerce. 1 pam.
São Paulo, Brazil-Commissão Geographica e Geologica. 1 pam.
Smithsonian Institution. 6 pam.
Tasmania-Gen. Mgr. of the Govt. Rys. 1 pam.
Tennessee-Min. Dept. 1 bound vol.
Union of South Africa-Dept. of Mines. 1 vol.
U. S.-Bureau of Manufacturers. 6 pam.
U. S.-Bureau of Mines. 2 pam.
U. S.-Bureau of the Census. 2 pam.
U. S.-Bureau of Yards and Docks. 1 pam.
U. S.-Civ. Service Comm. 1 bound vol.
U. S.-Coast and Geodetic Survey. 1 pam.
U. S.-Commr. of Labor. 1 bound vol.
U. S.-Forest Service. 18 pam.
U. S.-Geol. Survey. 1 bound vol., 7 vol., 8 pam.
U. S.-Interstate Commerce Comm. 3 bound vol., 10 pam.
U. S.-Library of Congress. 1 bound vol.
U. S.-Navy Dept. 2 pam.
U. S.-Office of Experiment Stations. 8 bound vol., 6 vol., 95 pam.
Washington-State Insp. of Coal Mines. 2 vol.
Wyoming-State Geologist. 1 pam.

BY PURCHASE

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben vom Verein deutscher Ingenieure. Hefte 105, 106, 107, 108, and 109. Julius Springer, Berlin, 1911.

Forscherarbeiten auf dem Gebiete Eisenbetons. Heft 17. Wilhelm Ernst & Sohn, Berlin, 1911.

Royal Commission on Sewage Disposal: Seventh Report of the Commissioners Appointed to Inquire and Report What Methods of Treating and Disposing of Sewage (Including any Liquid from any Factory or Manufacturing Process) may Properly be Adopted; Vol. III, Appendices, Pt. II. Published by His Majesty's Stationery Office, London, 1911.

Structural Engineering. By Joseph Husband and William Harby. Longmans, Green, and Co., New York, Bombay, and Calcutta, 1911.

Bearings and Their Lubrication. By L. P. Alford. McGraw-Hill Book Co., New York, London, and Berlin, 1911.

Analytical Mechanics, Comprising the Kinetics and Statics of Solids and Fluids. By Edwin H. Barton. Longmans, Green, and Co., London, New York, Bombay, and Calcutta, 1911.

Lippincott's New Gazetteer, A Complete Pronouncing Gazetteer or Geographical Dictionary of the World, With a Conspectus of the Thirteenth Census of the United States. Edited by Angelo Heilprin and Louis Heilprin. J. B. Lippincott Company, Philadelphia and London, 1911.

Punjab Rivers and Works: A Description of the Shifting Rivers of the Punjab Plains and of Works on Them, namely, Inundation Canals, Flood Embankments and River Training Works, with the Principles for Designing and Working Them. By E. S. Bellasis. Spon & Chamberlain, New York; E. & F. N. Spon, London.

The American Woods; Exhibited by Actual Specimens and with Copious Explanatory Text; Pt. XII. By Romeyn B. Hough. The Author, Lowville, N. Y., 1911.

SUMMARY OF ACCESSIONS

(From December 9th, 1911, to January 4th, 1912)

Donations (including 30 duplicates)	303
By purchase	13
Total	316

MEMBERSHIP

ADDITIONS

(From December 12th, 1911, to January 6th, 1912)

MEMBERS		Date of Membership.
HAWLEY, RALPH STEVENSON. Berkeley, Cal		Dec. 5, 1911
HENOCH, MILTON JACOB. Archt. and Engr. (Jenkinson & Henoch), 406 United Bank Bldg., Sioux City, Iowa.		Dec. 5, 1911
HORROCKS, JOHN IRVIN. Asst. Engr., C., M. & Puget Sound Ry., Room 617, White Bldg., Seattle, Wash		Dec. 5, 1911
INAGAKI, HYOTARO. Res. Engr., Imperial Govt. Ry., Ikegamimura, Ebaragori, Tokyo, Japan	Assoc. M. M.	Oct. 2, 1907 Oct. 31, 1911
LEIDY, GEORGE CRAIG. Asst. Supt., Semet Solvay Co., Steelton, Pa		June 30, 1911
McDONOUGH, CHARLES JOSEPH. Res. Engr., New York State Barge Canal, 42 Oxford Ave., Buffalo, N. Y.		Dec. 5, 1911
ORNELLAS, CHARLES EVARISTE D'. 4002 Carrientes, Buenos Aires, Argentine Republic		Oct 3, 1911
PHILBRICK, SHIRLEY SEAVEY. Engr. (Philbrick & Foster), Clarkston, Wash		Dec. 5, 1911
PORTER, SAM GRAHAM. Chf. Engr., Arkansas Val. Sugar Beet & Irrigated Land Co., Holly, Colo	Assoc. M. M.	Oct. 2, 1907 Dec. 5, 1911
SMITH, EDWIN GEORGE. Gen. Supt., Westmoreland Coal Co., Irwin, Pa		June 30, 1911
STROTHMAN, LOUIS EDWARD. Mgr. and Chf. Engr., Pumping Engine Dept., Allis-Chalmers Co., Milwaukee, Wis		Dec. 5, 1911
WAUGH, WILLIAM HAMMOND. Div. Engr., Bureau of Public Works, Manila, Philippine Islands	Jun. Assoc. M. M.	Oct. 5, 1911 June 5, 1907 Sept. 5, 1911

ASSOCIATE MEMBERS		
BROWN, GEORGE ROWELL. Asst. to Div. Engr., Div. No. 1, Mass. Highway Comm., 167 West Housatonic St., Pittsfield, Mass		Jan. 2, 1912
COLMAN, WILLIAM TUCKER. Engr., Lincoln Park, 665 Barry Ave., Chicago, Ill		Dec. 5, 1911
CONNER, ARTHUR WATSON. Asst. Engr., Bureau of Bridges, Office of New York State Engr. and Surv., Delmar, N. Y		Jan. 2, 1912
COOKINHAM, RICHARD SHERMAN. Insp., Irrig. Constr. for State of Idaho, Twin Falls, Idaho		June 30, 1911
DANN, ALEXANDER WILLIAM. Box 404, Vicksburg, Miss	Jun. Assoc. M.	Feb. 4, 1908 Dec. 5, 1911

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
ELY, GEORGE WELLS, JR. Engr., Pitometer Co., 184 South Oxford St., Brooklyn, N. Y.		Dec. 5, 1911
GANSER, SYLVAN EARLE. 107 Pembroke St., Boston, Mass.		Jan. 2, 1912
GIESEY, JESSE K. 170 Broadway, New York City		Dec. 5, 1911
HARRISON, EDWARD LEE. Designing Engr., G. M. Shaw & Co., 1503 Tenn. Trust Bldg., Memphis, Tenn.		Dec. 5, 1911
LEVY, ALFRED. New Works Engr., Ferrocarril Central Dominicano, Puerto Plata, Santo Domingo		Dec. 5, 1911
LICHTNER, WILLIAM OTTO. Asst. to Sanford E. Thompson, Newton Highlands, Mass.	Jun. Assoc. M.	Aug. 31, 1909 Jan. 2, 1912
LINCOLN, SAMUEL BICKNELL. Res. Engr., Lockwood, Greene & Co., Room 937, First National Bank Bldg., Chicago, Ill.		Dec. 5, 1911
LOUGHRAN, JAMES FRANCIS. County Supt. of Highways, Ulster County, 44 Main St., Kingston, N. Y.	Jun. Assoc. M.	Feb. 4, 1908 Dec. 5, 1911
McKENZIE, ANDREW JACKSON. City Engr. and Street Commr., Webb City, Mo.		Dec. 5, 1911
MALCOLM, WILLIAM DUNCAN. 250 North 11th St., Newark, N. J.		Dec. 5, 1911
MILLARD, WILLIAM JOHN. Kanyama, Manyiema, Kinshasa, Congo Belge, West Africa	Jun. Assoc. M.	Nov. 30, 1909 June 6, 1911
MORRIS, CHARLES CHESTER. Junior Engr., U. S. A., Care, U. S. Engr. Office, Corregidor, Philippine Islands		Oct. 3, 1911
NELSON, ELBERT JAMES. 44 Fountain Ave., Delaware, Ohio		Dec. 5, 1911
RANDALL, FRANK ALFRED. Chf. Engr., Morey, Newgard & Co., 1367 Sunnyside Ave., Chicago, Ill.		Dec. 5, 1911
ROBINSON, ARTHUR PIERCE. Vice-Pres., Insley Mfg. Co.; Vice-Pres. and Chf. Engr., W. E. Austin Machinery Co., 2 Spring St., Atlanta, Ga.		Dec. 5, 1911
SMITH, CLAIBORNE ELLIS. La Mesa, Cal.		Dec. 5, 1911
SMITH, WALTER DORR. Asst. Engr., Bridge Dept., City of Los Angeles, 4210 Gordon Ave., Los Angeles, Cal.		June 30, 1911
TAYLOR, WARREN CROSBY. Instr. in Civ. Eng., Union Coll., Schenectady, N. Y.	Jun. Assoc. M.	Feb. 4, 1908 Dec. 5, 1911
TAYLOR, WYLLYS HARD. Acting Dist. Engr., Dumaguete, Oriental Negros, Philippine Islands		Oct. 3, 1911
THOMES, EDWARD CALDERWOOD. City Engr.; Engr., Butler County R. R.; (Raudabaugh & Thomes), 119*a* North Main St., Poplar Bluff, Mo.		Dec. 5, 1911
VAN REENEN, REENEN JACOB. Engr., Irrig. Dept., Union of South Africa, P. O. Box 40, Cradock, Cape Province, South Africa		Oct. 3, 1911

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
VOLCK, ADALBERT GEORGE. With O'Rourke Eng. Constr. Co., 345 Fifth Ave. (Res., 456 Riverside Drive), New York City.	Jun. Assoc. M.	Dec. 1, 1908 Dec. 5, 1911

JUNIORS

ALVAREZ, ARTHUR CARL. In Chg., Civ. Eng. Testing Laboratory, and Instr. in Civ. Eng., Univ. of California, 1909 Dwight Way, Berkeley, Cal......	Dec. 5, 1911
BLAKESLEE, HAROLD LAW. Kitchawan, N. Y............	Dec. 5, 1911
CULLEY, MASSENA LARON. 672 North St., Jackson, Miss..	Dec. 5, 1911
FROST, WILLIS GEORGE. Highway Engr., San Mateo County, Redwood City, Cal......................	Dec. 5, 1911
GREEN, NATHANIEL WARREN. City Engr., Helena, Ark....	Dec. 5, 1911
HERCHKOVITZ, GEORGE EDWARD. Care, State Board of Assessors, State House, Trenton, N. J............	June 30, 1911
SMITH, CLAIRE HOWLAND WALLACE. Engr. in Chg., Trinchera Canal Co., Blanca, Colo...............	Dec. 5, 1911
SMITH, ROBERT HALL, JR. Masonry Insp., N. & W. Ry., Bandy, Va..................................	Dec. 5, 1911
STRANDBERG, GEORGE ROBERT. 1736 West 63d St., Seattle, Wash..................................	Dec. 5, 1911
STROMQUIST, WALTER GOTTFRID. Asst. Engr., State Water Survey, Urbana, Ill............................	Dec. 5, 1911
WIGHOLM, CARL AUGUST. 634 Sixtieth St., Oakland, Cal....................................	Dec. 5, 1911

RESIGNATIONS

MEMBERS

	Date of Resignation.
BOECKLIN, WERNER..................................	Dec. 31, 1911
HARDING, JAMES JUDSON.............................	Dec. 31, 1911
KROEBER, ADOLF THOMAS.............................	Dec. 31, 1911
SCOTT, ERNEST KAY.................................	Dec. 31, 1911

ASSOCIATE MEMBERS

BIELER, ALPHONSOS HENRY...........................	Dec. 31, 1911
BLYTHE, LUCIEN HOGUET.............................	Dec. 31, 1911
BRADY, JOSEPH.....................................	Dec. 31, 1911
BREWER, JESSE IRVING..............................	Dec. 31, 1911
DONALD, ROBERT L'AMY..............................	Dec. 31, 1911
ELLISON, EARL JEROME..............................	Dec. 31, 1911
FOX, WALTER GORDON................................	Dec. 31, 1911
GREENE, WILLIAM STEWART...........................	Dec. 31, 1911
HERRICK, JOHN JAMES...............................	Dec. 31, 1911
HERSEY, GUY ALFRED................................	Dec. 31, 1911
HOVEY, RAY PALMER.................................	Dec. 31, 1911

ASSOCIATE MEMBERS (*Continued*)	Date of Resignation.
MacNeille, Perry Robinson	Dec. 31, 1911
Sawyer, Percy	Dec. 31, 1911
Shonk, John Jenks	Dec. 31, 1911
Vier, Henry	Dec. 31, 1911
Williams, Howard Shay	Dec. 31, 1911
ASSOCIATES	
Hurst, George Joseph	Dec. 31, 1911
Huston, James Archibald	Dec. 31, 1911
Phipps, Lawrence Cowle	Dec. 31, 1911
Turrill, Sherman Marsh	Dec. 31, 1911
Usina, Domingo Anthony	Dec. 31, 1911
JUNIORS	
Banker, Edward Warren	Dec. 31, 1911
Bishop, Hiram Nelson	Dec. 31, 1911
Cook, Henry Aten	Dec. 31, 1911
Gearhart, Heber Gossler	Dec. 31, 1911
Hedden, Everett Burr	Dec. 31, 1911
Hitt, Rodney	Dec. 31, 1911
Hoeft, George Eliot	Dec. 31, 1911
Jones, Irving Paul	Dec. 31, 1911
Koenig, Louis	Dec. 31, 1911
Lake, Orloff	Dec. 31, 1911
Lewis, Wilfred	Dec. 31, 1911
Lynch, Edwin Lewis	Dec. 31, 1911
McCampbell, Alfred Kessinger	Dec. 31, 1911
Rome, Lyford	Dec. 31, 1911
Shoemaker, Harry	Dec 31, 1911
Wright, Albert Eugene	Dec. 31, 1911
Wright, Thomas Temple	Dec. 31, 1911

DEATHS

Douglas, Benjamin. Elected Junior, June 1st, 1887; Member, January 2d, 1890; died November 13th, 1911.

Gibbs, Nathan Jackson. Elected Associate Member, May 2d, 1911; died December 27th, 1911.

Mesa, Antonio Esteban. Elected Associate Member, January 1st, 1896; died February, 1911.

Sweesy, Thomas King. Elected Junior, August 31st, 1909; died September 2d, 1911.

Total Membership of the Society, January 6th, 1912, 6 332.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(December 9th, 1911, to January 5th, 1912)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1317 Spruce St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $4.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.

(57) *Colliery Guardian,* London, England.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions,* Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World,* 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 20c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 15c.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England.
(70) *Engineering Review,* New York City, 10c.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 10c.
(77) *Journal,* Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen,* Vienna, Austria.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Progressive Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings* Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Roadmaster and Foreman,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(94) *The Boiler Maker,* New York City, 10c.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 15c.
(98) *Journal,* Engrs. Soc. Pa., 219 Market St., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $1.50.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., $1.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Mining Engrs., London, England, 6 shillings.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.

LIST OF ARTICLES.

Bridges.

Renewal of Bridges on the B. & O. R. R.; Rapid Work with Hand Winches.* Charles Johnston. (13) Nov. 23.
Bridge Building in Alaska. (12) Serial beginning Dec. 1.
The Risorgimento Bridge, Rome.* W. Noble Twelvetrees, M. S. Ing. Civ. France. (11) Dec. 1.
Fireproofing Timber Trestles. (Paper read before the Am. Ry. Bridge and Bldg. Assoc.) (96) Dec. 7; (18) Dec. 16.
Highway Bridges. A. N. Johnson. (Paper read before the Am. Road Congress.) (14) Dec. 9.
The Erection of the Superstructure of the St. Louis Municipal Bridge (River Crossing).* S. W. Bowen. (86) Dec. 13.
Filling the Sprague Gulch Trestle on the Spokane, Portland & Seattle.* (15) Dec. 15.
Protection of Wooden Bridges from Fire.* (15) Dec. 15.
Novel Transportation Bridge in Great Britain.* F. C. Coleman. (46) Dec. 16.

*Illustrated.

Bridges—(Continued).

A Double-Track, 170-Foot Through Riveted Span, Having a Trough Floor Carried on Trough Floor Beams at Truss Panel Points.* (14) Dec. 16.
A Through Reinforced Concrete Arch Bridge at Lockland.* Fred E. Ayer. (14) Dec. 16.
Open Caisson Foundations of the Newark Turnpike Bridge.* (14) Dec. 16.
Reconstruction of Twenty-Second Street Bridge, Monongahela River, Pittsburgh.* Herman Laub. (62) Dec. 18.
A Reinforced Concrete Bridge.* J. H. de Warrenne Waller. (Abstract of paper read before Inst. C. E., Ireland.) (96) Dec. 21.
Heavy Concrete Piers and Abutments for Delaware River Bridge, New York, Ontario & Western Ry., Hancock, N. Y.* C. E. Knickerbocker, M. Am. Soc. C. E. (13) Dec. 21.
A Rapid Bridge Repair.* (20) Dec. 28.
The St. Croix River Arch Bridge; Minneapolis, St. Paul & Sault Ste. Marie Ry.* Pierce P. Furber. (13) Dec. 28.
The Bascule Span of the Passyunk Avenue Bridge.* (14) Dec. 30.
Sand Boxes for Camber Adjustments of Long Spans. (14) Dec. 30.
A Reinforced Concrete Arch Bridge Designed with Cantilever Ribs.* (14) Dec. 30.
The Risorgimento Concrete Bridge of 328-Foot Span. (From *Giornale del Genio Civil.*) (14) Dec. 30.
The Manhattan Bridge.* Howard R. Cummings. (10) Jan.
La Catastrophe de Montreuil-Bellay, Effondrement d'un Pont sur la Ligne d'Angers à Poitiers.* J. Latré. (33) Dec. 23.
Beiträge zur Theorie und Berechnung der im Eisenbetonbau üblichen Elastischen Bogen, Bogenstellungen und mehrstieligen Rahmen.* K. W. Schaechterle. (79) Vol. 17.
Wettbewerb zur Erlangung von Entwürfen für den Neubau der Alstädter-Brücke in Pforzheim.* H. Kayser. (51) Serial beginning Sup. No. 23.
Eisenbetonbrücke mit Compressolgründung über den Kanal Farkha in Alexandrien.* Walter Stross. (78) Nov. 27.
Herstellung von Eisenbetonbalkenbrücken ohne Lehrgerüst mit Hilfe von über die Oeffnung gespannten Kabeln. D. R.-P.* A. Seboldt. (78) Serial beginning Nov. 27.
Die Aufstellung neuerer eiserner Brücken. A. Rohn. (107) Serial beginning Dec. 2.

Electrical.

Siemen's Battery Signal Machine.* (21) Dec.
A Bismuth-Silver Thermopile. W. W. Coblentz. (3) Dec.
Automatic Telephone Exchanges.* (12) Dec. 1.
A Novel Country House Installation.* Francis H. Davies, A. M. I. E. E. (26) Dec. 1.
Bulk Supply at Turton, Lancs.* (26) Dec. 1.
The Utilization of Crude Petroleum for Electric Power Production.* (26) Dec. 8.
The Weston Synchroscope.* C. V. Drysdale. (73) Dec. 8.
A New Method of Measuring the Efficiency of Lightning Conductors. Eric Wurm. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Dec. 8.
The Opening up of the Amazon District by Wireless Telegraphy between Para and Lima.* E. Reinhard. (73) Serial beginning Dec. 8.
Modern Electric Methods of Measuring Temperature. J. Rautenkrantz. (Abstract from *Elektrotechnik und Maschinenbau.*) (73) Dec. 8.
The Characteristics of Series Instrument Transformers.* Arthur P. Young. (27) Serial beginning Dec. 9.
The Electric Iron-Reduction Plant at Trollhättan, Sweden.* (27) Dec. 9.
Electrically Driven Ice-Cream Factory; Producer Gas-Engine-Driven Plant of the J. M. Horton Ice Cream Co. in New York City.* (27) Dec. 9.
The Findings of the Investigators of Electrolysis in Underground Metallic Structures in Chicago.* (86) Dec. 13.
Method and Cost of Transferring Three 100-Pair Telephone Cables from the Original to a Combination Line.* R. E. Froisette. (86) Dec. 13.
Electric Power from Wind.* H. E. M. Kensit, M. I. E. E. (96) Dec. 14.
The Calculation of Shunt Field Coils. F. T. Chapman. (73) Dec. 15.
The Development of Syntonic and Directive Wireless Telegraphy.* S. M. Powell. (Abstract from paper read by Lieut. Tissot before Conf. de la Technique Moderne.) (26) Dec. 15.
Delray Station of Detroit Edison Company.* (27) Serial beginning Dec. 16.
Electric Street-Cleaning Apparatus.* (27) Dec. 16.
Electric Fire Trucks.* (27) Dec. 16.
The Electrification of the Shelton Mills.* W. H. Lake. (Paper read before the Staffordshire Iron and Steel Inst.) (22) Dec. 22.

*Illustrated.

Electrical—(Continued).

The First 110 000-Volt Installation in Europe.* E. G. Fischinger. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Dec. 22.
A Comparison of American Direct-Current Switchboard Voltmeters and Ammeters. T. T. Fitch and C. J. Huber. (Abstract from *Bulletin,* Bureau of Standards.) (73) Dec. 22.
A Method of Measuring Permeability by Means of Alternating Currents.* R. Beattie and H. Gerrard. (73) Dec. 22.
The Formation of Deposit by Transformer Oils.* Harold D. Symons, A. M. I. E. E. (26) Serial beginning Dec. 22.
The Preservation of Telegraph Poles.* (26) Dec. 22.
Experiments with Electrification During Growth of Garden and Greenhouse Plants.* (27) Dec. 23.
The Pabst Theatre, Milwaukee.* (27) Dec. 23.
Operation of Detectors in Wireless Telegraph Service.* L. H. Harris and John L. Hogan, Jr. (27) Dec. 30.
Some Notes on Isolated Plants. Percival R. Moses. (42) Jan.
Insulation as a Means of Minimizing Electrolysis in Underground Pipes. E. B. Rosa and Burton McCollum. (Paper read before the Am. Gas Inst.) (24) Serial beginning Jan. 1.
L'Usine Hydro-Electrique du Beaumont (Isère).* Maurice Gariel. (33) Dec. 9.

Marine.

The Arrangement and Construction of Oil Vessels.* J. Montgomerie. (10) Dec.
The Possibilities of the Internal-Combustion Engine Applied to Marine Propulsion.* Percy R. Allen. (10) Dec.
The Marine Steam Turbine.* Charles A. Parsons. (10) Dec.
Western Jetty Coal Shipping Plant, Immingham Docks, Great Central Railway.* (21) Dec.
The Argentine Battleships *Moreno* and *Rivadavia.** (12) Dec. 1.
The Best Arrangement for Combined Reciprocating and Turbine Engines on Steamships.* G. W. Dickie. (Abstract of paper read before the Soc. of Naval Archts. and Marine Engrs.) (47) Dec. 8.
The Canadian Pacific Railway's Oil Fuel-Burning T.-S. S. *Princess Alice.** (11) Dec. 8.
Some Impressions of Continental Marine Diesel Engine Practice.* (12) Serial beginning Dec. 8.
The Cunard Liner *Laconia* and the Rolling of Ships.* (11) Dec. 15.
Approximate Stability.* Arthur R. Liddell. (12) Dec. 15.
Twin-Screw Refrigerated Meat Steamer.* (12) Dec. 15.
Modern Methods of Bunkering Steamers.* F. C. Coleman. (19) Dec. 16.
Self-Dumping and Automatic Bailing Scow, a New Type for Refuse Disposal and Harbor Construction.* (46) Dec. 16.
The Suction of Vessels.* (12) Dec. 22.
The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia.* Frank E. Kirby and William T. Donnelly. (Abstract of paper read before the Soc. of Naval Archts. and Marine Engrs.) (96) Dec. 28.
Large Russian Vessels Propelled by Diesel Engines.* J. Rendell Wilson. (95) Jan.
Lighters and Lighterage in Harbor Freight Transference.* H. McL. Harding. (95) Jan.
Latest Dreadnoughts for South American Republics.* (95) Jan.
Extension du Port d'Anvers Construction du Tronçon du Bassin-Canal et des Deux Darses Correspondantes.* C. Missotten, L. Descans. (30) Dec.
Les Navires Sous-Marins *Holland.** M. Gouriet. (33) Dec. 16.
Schwimmkörper aus Eisenbeton.* Walther Stross. (79) Vol. 16.
Ein Motorboot aus Kunstmarmor.* Kurt Wissmann. (78) Dec. 14.

Mechanical.

Ball Bearings for Heavy Loads.* H. Gansslen. (4) Nov.
Making, Use and Care of Belting.* Chas. A. Schieren, Jr. (67) Dec.
A Practical Application of Fluorescence in Testing Oils for Industrial Purposes. Alexander E. Outerbridge, Jr. (3) Dec.
Pipe Threading Dies.* (From *Bulletin,* National Tube Company.) (94) Dec.
A New Crude Oil Engine.* (12) Dec. 1.
Recent Research Work on the Properties of Steam. C. A. M. Smith and A. G. Warren. (11) Serial beginning Dec. 1.
Short-Stroke Work on Planing-Machines.* (11) Dec. 1.
Aeroplane Efficiency.* Algernon E. Berriman, M. Inst. A. E. (29) Dec. 1.
Coal-Cutting Machinery.* W. Bolton Shaw. (Paper read before the Manchester Assoc. of Engrs.) (22) Dec. 1; (47) Dec. 8; (73) Dec. 22.
Actual Leakage in Unaccounted-for Gas. Jacob D. Von Maur. (Abstract of a paper read before the Am. Gas. Inst.) (66) Dec. 5.

*Illustrated.

Mechanical—(Continued).

High Pressure Gas Application. E. W. Smith. (Paper read before the Manchester University.) (66) Dec. 5.
A Survey of Gas Photometry and Calorimetry. Charles O. Bond. (Abstract of paper read before the Am. Gas Inst.) (66) Dec. 5.
Motor-Driven Centrifugal Pump Fire Engine.* (12) Dec. 8.
Construction of Automobile Radiators.* I. P. F. (101) Dec. 8.
Speed Reduction Gear for Steam Turbines.* (47) Dec. 8.
Power from Peat. (12) Dec. 8.
Steam Shovel Dipper Trips.* (From *Canal Record.*) (14) Dec. 9.
Power Plant of the Ayer Mill.* Warren O. Rogers. (64) Dec. 12.
Coal-Gas Purification. Harold E. Stone. (Paper read before the Midland Junior Gas Eng. Assoc.) (66) Dec. 12.
Methods of Analysis of Cost of Steam Shovel Work. (Abstract of Report, Construction Service Co.) (86) Dec. 13.
New Bituminous Gas Producer.* (20) Dec. 14.
Motor Trucks. C. R. Hoyme. (Paper read before the Philadelphia Foundrymen's Assoc.) (20) Dec. 14.
Problems Involved in the Selection of Machinery for the Manufacture of Portland Cement.* Paul C. Van Zandt, M. Am. Soc. M. E. (13) Dec. 14.
The American District Steam Company.* (20) Dec. 14.
The Selection and Proportion of Aggregates for Concrete. (96) Dec. 14.
The Influence of Detail on the Development of the Automobile. L. A. Legros, M. I. M. E. (Abstract of paper read before the Inst. of Automobile Engrs.) (47) Dec. 15.
Producer Gas. J. A. Weil. (Abstract of paper read before the Manchester Assoc. of Engrs.) (47) Dec. 15.
Kiln Flue Regulation.* Dwight T. Farnham. (Paper read before the Am. Ceramic Soc.) (76) Dec. 15.
Ventilation of Fuel Gas Appliances. James H. Walker. (Paper read before the National Commercial Gas Assoc.)' (83) Dec. 15.
The Modern Gas Fixture. Charles E. Ummach. (Paper read before the National Commercial Gas. Assoc. (83) Dec. 15.
The H. W. C. Apparatus for Instruction and Research in Gas-Testing.* (57) Dec. 15.
The Stability of Aeroplanes.* A. P. Thurston. (19) Dec. 16.
The Strength of an Aeroplane.* (46) Dec. 16.
Handling Concrete at Salmon River Dam.* (16) Dec. 16.
An Exhibit and Description of a Model Glass Gas Works. A. F. Traver. (Paper read before the National Commercial Gas Assoc.) (24) Dec. 18.
Manufacturing of Gas Mantels from Artificial Fibers.* S. Guldbransen. (Paper read before the National Commercial Gas Assoc.) (24) Serial beginning Dec. 25.
Public Lighting. E. Garsed. (Paper read before the Yorkshire Junior Gas Assoc.) (66) Dec. 19.
Gas-Flow Measurement by the Pitot Tube.* J. W. Balten. (Abstract of paper read before the Am. Gas Inst.) (66) Dec. 19.
Chemical Control of Gas-Works.* (66) Dec. 19.
Hot Water.* S. A. Carpenter. (Paper read before the London and Southern District Junior Gas Assoc.) (66) Dec. 19.
A 15 000-h.p. Coke Oven Gas Engine Plant.* C. A. Tupper. (20) Dec. 21.
Wire Flattening Mill.* (20) Dec. 21.
A Centrifugal Clarifier and Filter.* (13) Dec. 21.
Drawings for the Pattern and Core-Box of a Francis Turbine Runner.* George M. Peek. (13) Dec. 21.
The Carbonization of Coal. Vivian B. Lewes. (29) Dec. 22.
Mechanical Stokers at the Mines de Dourges Co.'s Works, France.* (11) Dec. 22.
The Refrigerated-Meat Industry of South America.* (11) Dec. 22.
Coal Washing Plant at the Cramlington Colliery.* (12) Dec. 22.
Deterioration and Spontaneous Heating of Coal in Storage. Horace C. Porter and F. K. Ovitz. (Abstract of paper read before the Am. Chem. Soc.) (14) Dec. 23; (103) Dec. 23; (64) Jan. 2.
Isolated Power for Making Shoes.* W. B. Wilkinson. (64) Dec. 19.
New Generating Station, Portland, Oregon.* Edward A. West. (64) Dec. 26.
The 69th St. Car-Transfer Bridge of the New York Central & Hudson River R. R. at New York City.* (13) Dec. 28.
Electrical Equipment of Gary Coke Plant.* (20) Dec. 28.
Machine Molding for Large Castings.* (20) Dec. 28.
Methods of Dust Extraction on Cotton-Carding Engines.* J. H. Crabtree. (46) Dec. 30.
A Modern Electrically Operated Brick Plant.* O. F. Metz. (27) Dec. 30.
The Condensation of Steam.* Theodore Rich. (10) Jan.
Some Recent Developments in British Machine-Tool Design.* Joseph Horner. (10) Jan.

---

*Illustrated.

Mechanical—(Continued).

The Electric Furnace for Small Steel Castings. (105) Jan.
New Plant of Best Manufacturing Company, at Oakmont, Pa.* (62) Jan. 1.
Plants for Making Sulphate of Ammonia.* C. G. Atwater. (Paper read before the Am. Gas Inst.) (83) Jan. 1.
Atlantic Highlands Gas Supply.* R. H. Garrison. (83) Jan. 1.
Power System of the Pacific Mills.* (64) Jan. 2.
L'Hélice Propulsive.* Rodolphe Soreau. (32) Sept.
Installation d'une Fabrique de Ciment Portland par la Voie Demi-Humide.* (84) Nov.
Four à Bascule et à Récupération pour Fonderies de Bronze, Système Morgan (breveté).* (34) Dec.
Essais pour la Détermination du Mode de Travail le Plus Favorable de la Machine à Rectifier.* Willy Pockrandt. (93) Dec.
Le Concours d'Appareils Militaires d'Aviation (Reims, octobre-novembre 1911).* G. Espitallier. (33) Serial beginning Dec. 2.
Le Lancement des Projectiles par les Aéroplanes, Appareil de Pointage, Système Scott.* (33) Dec. 16.
Transmission à Distance de Mouvements Discontinus Système Herzmark.* Ch. Jacquin. (33) Dec. 16.
La IIIe Exposition Internationale de Locomotion aérienne (Paris 1912).* G. Espitallier. (33) Dec. 23.
Die neuere Entwicklung der Fördermaschinenantriebe und der Sicherheitsvorrichtungen.* A. Wallichs. (48) Serial beginning Dec. 2.
Die Wasserdruckmomente der Drehschaufeln von Zentripetal-Francis-Turbinen.* R. Camerer. (48) Dec. 2.
Ueber die Verwendung von Koksofengas im Martinofen.* Oskar Simmersbach. (50) Serial beginning Dec. 7.
Die Anwendung der Gesetze der Hydraulik auf der Berechnung der Flammöfen. (50) Serial beginning Dec. 7.
Untersuchungen über das allgemeine Verhalten des Geschwindigkeitskoeffizienten von Leitvorrichtungen des praktischen Dampfturbinenbaues.* Paul Christlein. (48) Dec. 16.
Gas- oder Dampfbetrieb auf Hüttenwerken. M. Langer. (50) Dec. 21.

Metallurgical.

Efficiency in Ore Roasting. Arthur S. Dwight. (6) Nov.
Chispas Cyanide Plant, Arizpe, Sonora, Mexico.* Edward L. Dufourcq. (6) Nov.
Volatilization of Gold and Silver from Their Copper Alloys. Edward F. Kern and Albert A. Heimrod. (6) Nov.
The Hering Pinch Effect Furnace. E. Kilburn Scott. (Abstract of paper read before the Faraday Soc.) (22) Dec. 1.
Titanium and Low Carbon Basic Steel.* G. B. Waterhouse. (20) Dec. 14.
Thin-Lined Blast Furnace Construction.* (20) Dec. 28.
Treatment of Broken Hill Ores.* Wm. Poole. (45) Jan.
Cyaniding by Continuous Decantation in Clear County, Colorado.* H. C. Parmelee. (105) Jan.
Calculation of Furnace Charges. Regis Chauvenet. (105) Jan.
Metallurgy of Mercur Gold Ores.* Theo. P. Holt. (45) Jan.
Four Martin pour Moulages d'Aciers et Aciers Spéciaux de l'Usine de Tsaritsyne (Russie).* E. Richarme. (93) Dec.
Die Schmelzpunkte der Segerkegel 022 bis 15.* Reinhold Rieke. (80) Dec. 14.

Military.

Electrical Methods of Intercommunication for Military Purposes.* George O. Squier. (3) Dec.
The Strength of Thick Hollow Cylinders under Internal Pressure.* (Guns.) Gilbert Cook, A. M. Inst. C. E. (11) Dec. 15.
Coast Batteries: Can They be Improved?* T. H. E. Anderson. (From *Journal, Royal Artillery.*) (44) Jan.
Notes on the Theory and Practice of Field Fortification. F. Golenkin. (From *Royal Engineers Journal.*) (100) Jan.

Mining.

Wire Ropes as Applied to Mining. Dugald Baird. (106) Vol. 42 Pt. 1; (59) Vol. 34 Pt. 1.
The Holmes-Ralph Gas-Detecting Portable Electric Lamp.* George J. Ralph. (106) Vol. 42 Pt. 1.
An Outburst of Coal and Fire-Damp at Valleyfield Colliery, Newmills, Fife. Henry Rowan. (59) Vol. 34 Pt. 1.
The Microscopical Examination of Coal and Its Use in Determining the Inflammable Constituents Present Therein. James Lomax. (106) Vol. 42 Pt. 1.

*Illustrated.

Mining—(Continued).

Luminous Electric Mine-Shaft Signalling.* J. C. Eadie. (106) Vol. 42 Pt. 1.
Experiments on Liquid Mixtures for Laying Coal-Dust. W. M. Thornton. (106) Vol. 42 Pt. 1.
The Shaw Hemsworth Overwinder.* Thomas Beach. (106) Vol. 42 Pt. 1.
The Causes and the Prevention of Coal Mine Explosions. Edward K. Judd. (6) Nov.
New French Regulations on the Use of Electricity in Mines. (22) Dec. 1.
Molybdenum.* (96) Dec. 7.
A New System of Screening and Loading Coal.* (22) Dec. 8.
Using Dynamite in Excavation Work.* M. Richards. (101) Dec. 8.
Electric Winding Gear at the West Rand Consolidated Gold-Mines.* (11) Dec. 8.
Keeping Mining Costs at Joplin. Otto Ruhl. (16) Dec. 9.
Ore Handling at Ray, Arizona.* C. L. Edholm. (16) Dec. 9.
Marysville Dredge No. 4.* Robert E. Cranston. (103) Dec. 9.
Skip for a Vertical Shaft.* (103) Dec. 9.
Pokorny and Wittekind Turbo-Compressors for the Rand Mines.* (11) Dec. 15.
The Action and Control of Differently Constituted Coal Roofs. W. H. Hepplewhite. (Paper read before the Midland Counties Inst. of Engrs.) (22) Dec. 15.
A Dry Land Dredging Machine.* Lewis H. Eddy. (16) Dec. 16.
Electric Hoists for Mines. D. B. Rushmore. (16) Dec. 16.
Stamp-Battery Cam-Shafts.* Charles T. Hutchinson. (103) Dec. 16
The Braden Copper Mines. Pope Yeatman. (103) Dec. 16; (16) Dec. 9.
Methods of Driving by Gas Engines for Collieries.* Alan E. L. Chorlton, M. I. M. E. (Abstract of paper read before the Midland Inst. of Min., Civ. and Mech. Engrs.) (47) Dec. 22.
Some Notes on Porcupine.* S. F. Shaw. (16) Dec. 23.
Dredging for Placer Tin in Alaska.* Lewis H. Eddy. (16) Dec. 23.
Mine and Mill of the Brakpan Mines, Ltd.* H. S. Gieser and C. A. Tupper. (103) Dec. 23.
The Shape of a Shaft.* E. Mackay Heriot. (16) Dec. 30.
Exhaust Steam Turbines at Mines.* John C. Cunningham. (Paper read before the Australasian Inst. of Min. Engrs.) (45) Jan.
Mining in the Tintic District, Utah.* Leroy Palmer. (45) Jan.
Extinguishing the Majestic Mine Fire.* R. Y. Williams. (45) Jan.
Shafts for American Coal Mines.* R. G. Johnson. (Paper read before the West Virginia Min. Inst.) (45) Jan.
Model Steel Tipple at Annabelle Mines.* Wm. Archie Weldin. (45) Jan.
Prices of Coal and Materials Used in Mining Compared. E. N. Zern. (62) Jan. 1.

Miscellaneous.

Pyrometry. S. H. Stupakoff. (Abstract of paper read before the Am. Foundrymen's Assoc.) (47) Dec. 8.
Legal Compensation for Engineers Engaged on Public Works in Indiana. Edwin E. Watts. (From paper read before the Indiana Eng. Soc.) (13) Dec. 14.
Resultats de Divers Essais faits dans les Pépinières de Groenendael par l'Administration des Eaux et Forêts. E. Hermans. (30) Dec.
Installations de Sureté pour la Manutention des Liquides Inflammables Appareils Martini et Huneke.* M. François. (33) Dec. 9.
Der Wärmeübergang im Kreuzstrom.* William Nusselt. (48) Dec. 2.

Municipal.

Smokeless Combustion of Bituminous Coal in the Pittsburgh District.* Mirabeau Sims. (58) Nov.
Smoke Abatement in Great Britain. John B. C. Kershaw. (64) Dec. 19; (47) Dec. 1.
Public Lighting of the City of London. (66) Dec. 5.
Cement Concrete Roads.* (Abstract from Annual Report on Highway Improvement, Ontario.) (96) Dec. 7.
Methods Employed by the New York State Highway Department in Testing Road Stone and Bituminous Materials. (86) Dec. 20.
Street Cleaning Methods and Costs at Washington, D. C. (86) Dec. 20.
Considerations Affecting the Selection of Types of Pavements Best Adapted for Use upon a Given Street. (86) Dec. 20.
Asphalt Macadam Construction at Carlisle, Pa.* C. A. Bingham, Assoc. M. Am. Soc. C. E. (86) Dec. 20.
The Effect of Napthalene in Road Tars. (Abstract from *Circular*, U. S. Office of Public Roads.) (13) Dec. 21.
Practical Road Building. John N. Edy. (60) Jan.
Dustless Roads and Bituminous Binders. Wm. F. Prouty. (10) Jan.
Shell Roads.* W. W. Crosby. (Paper read before the Am. Assoc. for the Advancement of Science.) (86) Jan. 3.
History of Tar-Concrete Pavements in Ontario. W. A. McLean. (Paper read before the Am. Assoc. for the Advancement of Science.) (86) Jan. 3.

*Illustrated.

Municipal—(Continued).

Eisenbetondurchlass in Kortezwaag (Niederlande).* Richard Hoffman. (78) Serial beginning Dec. 14.
Städtebauliche Entwicklung von Prag.* A. E. Brinckmann. (51) Serial beginning Dec. 16.

Railroads.

The New York Tunnel Extenson of the Pennsylvania Railroad. Contractors' Plant for East River Tunnels.* Henry Japp, M. Am. Soc. C. E. (54) Vol. 69.
The New York Tunnel Extension of the Pennsylvania Railroad. The Lining of the Four Permanent Shafts of the East River Division.* F. M. Green, Assoc. M. Am. Soc. C. E. (54) Vol. 69.
The New York Tunnel Extension of the Pennsylvania Railroad. The Long Island Approaches to the East River Tunnels.* George C. Clarke, M. Am. Soc. C. E. (54) Vol. 69.
The New York Tunnel Extension of the Pennsylvania Railroad. The Sunnyside Yard.* Louis H. Barker. (54) Vol. 69.
The New York Tunnel Extension of the Pennsylvania Railroad. Certain Engineering Structures of the New York Terminal Area.* George B. Francis and Joseph H. O'Brien, Members, Am. Soc. C. E. (54) Vol. 69.
The New York Tunnel Extension of the Pennsylvania Railroad. Station Construction, Road, Track, Yard Equipment, Electric Traction, and Locomotives.* George Gibbs, M. Am. Soc. C. E. (54) Vol. 69.
Development of the Railroads of North America and of Their Control by the State. James Douglas. (8) Oct.
Use of Denatured Alcohol in Railway Service. Michael Schwarz. (61) Nov. 21.
Locomotives on Turkish Railways.* (21) Dec.
Semi-Automatic Signals, Great Central Railway.* (21) Dec.
2-8-2 or Mikado Type Locomotives; Illinois Central Railroad.* (21) Dec.
Proposed Specifications for Postal Cars. (25) Dec.
Service of Mallet Articulated Locomotives. (25) Dec.
New Electrical System of Cab-Signalling.* (25) Dec.
Test of a Mallet Locomotive Equipped with Superheater and Brick Arch, New York Central and Hudson River Railroad.* (25) Dec.
New Mikado Type Locomotives, Southern Ry. Co.* (25) Dec.
40-Ton High-Side Bogie Wagon; Central Argentine Railway.* (21) Dec.
The Safe Signalling System.* (21) Dec.
4-8-2 Locomotives. (21) Dec.
New York Tunnel Extension, Pennsylvania R. R.* (87) Dec.
Sweetwater Terminal, A., T. & S. F. Ry.* (87) Dec.
Operation of a Roberts Track Laying Machine.* C. L. V. (87) Dec.
Reinforced Concrete Roundhouse for the New Haven R. R.* (87) Dec.
Large Capacity Tank Car.* (15) Dec. 8.
The Mallet Locomotive on American Railways.* (12) Serial beginning Dec. 8.
The Design of Express Locomotives. E. Cecil Poultney. (Abstract of paper read before the Birmingham Assoc. of Mech. Engrs.) (47) Dec. 8.
Tests of Superheater Freight Engines on the Chicago & North Western. (15) Dec. 8.
Fuel Oil Installation on the Great Northern Ry.* E. E. Adams. (18) Dec. 9.
Electric Locomotives for the Portland, Gray & Lewiston Ry.* (18) Dec. 9.
New Tunnel to Improve Baltimore & Ohio Mountain Operation.* (14) Dec. 9.
London to Brighton in Forty-Five Minutes, the Future of Railway Electrification.* Philip Dawson. (Abstract of paper read before the Royal Automobile Club.) (73) Dec. 15; (12) Dec. 15.
Passenger Locomotive for the Southern Pacific Railway, U. S. A.* (11) Dec. 15.
A New Type of 30-Ton Trolley Wagon for the North British Railway Company.* (22) Dec. 15.
The Santa Fe Train de Luxe.* (15) Dec. 15.
Mikado Locomotives for the Great Northern.* (15) Dec. 15.
Mathematical Relations Between Increases in Cost and Increases in Durability in Steel Rails. B. E. V. Luty. (15) Dec. 15.
Concrete Sign Posts.* (15) Dec. 15.
Fireless Locomotives; Using Superheated Water in Place of a Coal Fire.* (19) Dec. 16.
The Most Powerful European Express Engine.* (46) Dec. 16.
An Unusual Retaining Wall for a Railroad Fill.* (14) Dec. 16.
Methods of Drifting in Swelling and Running Ground (Tunnels).* Harold Lakes. (Abstract from *Engineering and Mining World.*) (86) Dec. 20.
Profiles of Railway Lines from the Atlantic Coast to the Great Lakes.* (13) Dec. 21.
Gasoline Motor Car.* (15) Dec. 22.
Driving the Big Savage Railroad Tunnel with Compressed Air.* (14) Dec. 23.
Gasoline Motor Cars for the Victorian Railways, Australia.* (17) Dec. 23.

*Illustrated.

Railroads—(Continued).

Railway Station Illumination. Hadyn T. Harrison. (Paper read before the Illuminating Eng. Soc.) (66) Dec. 26.
Romapac Rail Installations in Chicago and Elsewhere.* (17) Dec. 23.
Appraisal of the Spokane and Inland Empire Electric Railroad System. Henry L. Gray. (86) Dec. 27.
The Marine Terminal of the Grand Trunk Pacific Railway, Prince Rupert, British Columbia.* Frank E. Kirby and William T. Donnelly. (Abstract of paper read before the Soc. of Naval Archts. and Marine Engrs.) (96) Dec. 28.
The 69th St. Car-Transfer Bridge of the New York Central & Hudson River R. R. at New York City.* (13) Dec. 28.
Experimental Pacific Type Locomotive.* (15) Dec. 29.
Steel Coaches; Baltimore & Ohio.* (15) Dec. 29.
Joliet Extension of the Chicago, Ottawa & Peoria Railway.* (17) Dec. 30.
Storage Battery Mine Locomotive.* H. B. Barnes. (16) Dec. 30.
A Dispute over Grading Classification. (14) Dec. 30.
Cost of Track Laying on the Erie Railroad. (86) Jan. 3.
Wagon Tombereau de 20^{T} avec Frein à Levier à Main, à Rochet et à 4 Sabots de la Compagnie des Chemins de Fer de l'Est.* (38) Dec.
Frein à Rochet, à Main avec Timonerie Westinghouse à 4 Sabots Appliqué aux Wagons à Deux Essieux Chargeant 20 Tonnes et aux Wagons à Bogies de la Compagine des Chemins de Fer de l'Est.* (38) Dec.
Die Herstellung neuer Gleise aus alten Schienen im Grossbetriebe unter besonderer Berücksichtigung der Säge- und Bohr-Maschinenanlage auf Bahnhof Dirschau. K. Metzel. (102) Serial beginning Dec. 1.
Der Bau eiserner Personenwagen auf den Eisenbahnen der Vereinigten Staaten von Amerika.* F. Gutbrod. (48) Serial beginning Dec. 2.
Die Umgestaltung des Hauptbahnhofes in München.* (51) Serial beginning Dec. 6.
Ueber den Einfluss von Lokomotivgasen auf frischen Mörtel. E. v. Willmann. (78) Dec. 14.
Heissdampf-Tenderlokomotive E^{b} 3/5 der S. B. B.* (107) Dec. 16.
Einrichtungen zur Verschärfung der Streckensignale.* L. Kohlfürst. (107) Serial beginning Dec. 16.

Railroads, Street.

Central Station Design. Irving E. Moultrop. (8) Serial beginning Oct.
Chicago River Tunnels—Their History and Method of Reconstruction.* William Artingstall. (4) Nov.
Controlling Brakes for Trolleys on Transfer Booms. Frey Broberg. (From *Industrial Engineering.*) (96) Dec. 7.
Power Plant Extension of the Denver City Tramway Company.* (17) Dec. 9.
Study of Operating Characteristics of Chicago Railway Company's Cars as Influenced by Coasting Time.* (17) Dec. 9.
Papers Read at New York State Association Convention on the Pay-as-You-Enter Cars. (17) Dec. 9.
The Thirty-eighth Street Substation of the Brooklyn Rapid Transit System.* (17) Dec. 16.
The Electric Trolley Omnibus System and Railless Traction.* Horace M. Boot. M. I. Mech. E. (Paper read before the Inst. of Mun. Engrs.) (104) Serial beginning Dec. 22.
Power Generation and Distribution System of the Boston Elevated Railway.* (17) Dec. 30.

Sanitation.

Foundation and Sewer Work: Cost and Comments.* Victor Windett. (4) Nov.
Disinfection Experiments with Hypochlorite of Calcium on the Carnegie Swimming Pool, Yale University. Leo F. Rettger and Samuel C. Markley. (13) Nov. 23.
Specifications for a 10-Year Refuse Disposal Contract, Boston, Mass. (13) Nov. 23.
Experiments on Currents, Velocities and Sedimentation in a Modified Cologne Tank.* N. Adelbert Brown. (36) Dec.
Highway, Water Supply and Sewerage Works in Toronto.* C. H. Rust. (104) Dec. 1.
Some Observations on the Principles of Sewage Purification. W. Owen Travis. (Paper read before the Assoc. of Managers of Sewage Disposal Works.) (104) Dec. 8.
Operating Results of the Garbage-Reduction Works at Cleveland and Columbus, Ohio. John H. Gregory, M. Am. Soc. C. E. (14) Dec. 9.
Methods and Cost of Purifying Sewage in the State of Ohio. R. Winthrop Pratt, M. Am. Soc. C. E. (86) Dec. 13.

*Illustrated.

Sanitation—(Continued).

Engineering Problems Connected with Biological Sewage Treatment.* T. Aird Murray, M. Can. Soc. C. E. (Paper read before the Canadian Public Health Assoc.) (96) Dec. 14.
Heating, Ventilating and Air—Washington System in a Large Modern Factory.* (96) Dec. 14.
Constructing a Deep Sewer of Brick and of Concrete-Lined Cast-Iron for the London County Council, England. R. M. Gloyne, M. Inst. C. E. (Abstract of paper read before the Inst. of Mun. and County Engrs.) (13) Dec. 14.
Plumbing in Hotel Taft at New Haven.* (101) Dec. 15.
Self-Dumping and Automatic Bailing Scow, a New Type for Refuse Disposal and Harbor Construction.* (46) Dec. 16.
Hot Water Heating for High Buildings.* Ira N. Evans. (64) Dec. 19.
Electrolytic Sewage Treatment at Oklahoma City, Including Estimated Cost of Operation.* Howard V. Hinckley. (86) Dec. 20.
Furnace Heating in a Bungalow.* (101) Dec. 22.
Report on Methods of Refuse Disposal at Toronto. (14) Dec. 23.
The Relation of the Putrescibility of the Settling and Non-Settling Suspended Matter in Sewage. Arthur Lederer. (Paper read before the Am. Public Health Assoc.) (14) Dec. 23.
Milwaukee City Garbage Electrical Plant.* (27) Dec. 23.
The Sewer System of Havana. G. C. Scherer, Assoc. Am. Soc. C. E. (From *Concrete Age.*) (19) Dec. 23.
Amount of Ground Water Infiltration into Sewers in Various Cities: Methods of Waterproofing Sewers. (86) Dec. 27.
The Preparation and Enforcement of Drainage Specifications. J. L. Parsons. (86) Dec. 27.
The Calumet Sag Channel of the Sanitary District of Chicago.* (86) Dec. 27.
The Portable Emergency Hypochlorite Water-Disinfecting Plant of the Kansas State Board of Health.* W. C. Hoad. (13) Dec. 28.
The Problem of the Great Lakes.* (96) Dec. 28.
Recent Methods of Sewage Clarification and Sludge Treatment in Germany. E. Kuichling. (13) Dec. 28.
Steam Heating System in Residence.* (101) Dec. 29.
A New Sprinkling Filter at Reading.* E. Sherman Chase. (14) Dec. 30.
Present European Practice in Sewage Purification.* R. L. Sackett. (Paper read before the Indiana Eng. Soc.) (60) Jan.
Engineering Procedure in the Brooklyn Bureau of Sewers. J. B. Van Vleck. (Paper read before the Brooklyn Engrs.' Club.) (86) Jan. 3.
Heating of Mansion by Five Furnaces.* (101) Jan. 5.
Plumbing in New York Public Library.* (101) Jan. 5.
Gusseiserne Radiatoren. E. Mueller. (50) Serial beginning Nov. 30.

Structural.

Diagrams for the Design of Forms for Concrete Slabs.* R. C. Yeoman. (From *Engineering Annual,* Civil Eng. Soc., Valparaiso Univ.) (13) Nov. 23.
Economical Design of Reinforced Concrete Beams. R. B. Ketchum. (Paper read before the Utah Soc. of Engrs.) (1) Dec.
The Strength of Bond on Joining Old Concrete to New.* J. M. Fitzgerald and Albert Diament. (36) Dec.
Experiments on the Reliability of Mild Steels. C. E. Stromeyer. (Paper read before the Manchester Steam Users' Assoc.) (47) Dec. 1.
An Unusual Advertising Tower.* Samuel T. Williams. (14) Dec. 9.
Cantilever Construction for a Warehouse Extension.* (14) Dec. 9.
Steel Superstructure of the United Fire Companies' Building, New York.* (14) Dec. 9.
Portland Cement on Public Works. General Thornhill Edwards, Assoc. M. Inst. C. E. (Paper read before the Inst. of Water Engrs.) (104) Dec. 15.
A Reinforced Concrete Retaining Wall at Bury.* (12) Dec. 15.
Using Steel Foundation Piles and Girders in Very Narrow Clearance.* (14) Dec. 16.
Constructing a Gadd and Mason Holder in a Column-Guided Holder Tank.* W. Dawes. (Paper read before the Yorkshire Junior Gas Assoc.) (66) Dec. 19.
Rapid Destruction of Timber Beams from Dry Rot.* (13) Dec. 21.
Fireproofing. Richard L. Humphrey. (Abstract of paper read before the Concrete Inst.) (96) Dec. 21.
A Roof Shield for Steel Smokestacks.* (13) Dec. 21.
Steel Specifications from the Commercial Point of View. H. B. Strange. (Abstract of paper read before the Junior Institution of Engrs.) (22) Dec. 22; (47) Dec. 22.
A Chimney-Stack of Reinforced Concrete.* Oscar Faber, A. M. I. C. E. (11) Dec. 22.
The Concrete Substructure of the Seaman's Church Institute.* (14) Dec. 23.
Constructing the Foundations for a Large Gasholder.* (14) Dec. 23.

*Illustrated.

Structural—(Continued).

Heavy Girder Construction in the Adolphus Hotel at Dallas.* (14) Dec. 23.
The Design and Erection of a Large Foundry Building.* Merrill Hibbard. (14) Dec. 23.
Straightening Two Brick Chimneys that Leaned During Construction. (14) Dec. 23.
Volatilization of Various Fractions of Creosote After Their Injection into Wood.* (86) Dec. 27.
The Collapse of the Reinforced-Concrete Building for the Prest-O-Lite Co., Under Construction at Indianapolis, Ind.* Theodore L. Condron, M. Am. Soc. C. E. (13) Serial beginning Dec. 28; (14) Dec. 16.
An Inverted-Arch Foundation of Reinforced Concrete.* James E. Payne. (13) Dec. 28.
Driving Concrete Piles with a 12 000-Pound Hammer. (14) Dec. 30.
Underpinning Brick Dwellings on Concrete Piers and Girders. (14) Dec. 30.
Deep Open Excavation in Quicksand.* (14) Dec. 30.
Uses and Misuses of Concrete and Reinforced Concrete. De Witt V. Moore, M. Am. Soc. E. Contrs. (Paper read before the Indianapolis Architects' Assoc.) (60) Jan.
Analyses for Moments in Three Types of Reinforced Concrete Floors.* S. Ingberg. (86) Jan. 3.
Sur la Constitution et la Formation du Ciment Portland. E. Leduc. (92) Nov.
Un Point Faible du Béton Armé l'Adhérence. Ad. Klein. (84) Nov.
La Contraction du Béton Armé et non Armé. (84) Nov.
Note sur l'Etablissement des Fondations du Bâtiment des Services de l'Etat au Port de Zeebrugge.* Ch. Piens. (30) Dec.
Beiträge zur Theorie und Berechnung der im Eisenbetonbau üblichen Elastischen Bogen, Bogenstellungen und mehrstieligen Rahmen.* K. W. Schaechterle. (79) Vol. 17.
Betonhohlblockbauten im Erdbebengebiet in Calabrien.* (51) Sup. No. 23.
Die Betonkontrolle beim Neubau des K. u. K. Kriegsministerialgebäudes in Wien.* J. Kromus. (68) Serial beginning No. 27.
Einige neuere Siloausführungen der Wayss & Freytag A.-G., Berlin.* S. Sor. (78) Nov. 27.
Einige Anwendungen des umschnürten Betons (System Abramoff-Magid.)* Franz Boerner. (78) Serial beginning Nov. 27.
Einheitsfarben zur Kennzeichnung von Rohrleitungen in industriellen Betrieben.* (50) Nov. 30; (48) Dec. 2.
Versuche mit Aluminium geschweisst und ungeschweisst, bei gewöhnlicher und höherer Temperatur.* R. Baumann. (48) Dec. 2.
Fundationsarbeiten mit Eimer-Bagger.* G. Lüscher. (107) Dec. 9.
Das kleine Ziegelemass in Oesterreich. (80) Dec. 12.
Zerstörung von Mörtel.* Alfred H. White. (80) Serial beginning Dec. 9.
Berechnung kontinuierlicher Eisenbetonträger mit Rücksicht auf die Wirkung der Vouten.* A. Strassner. (78) Serial beginning Dec. 14.
Ein Beitrag zum Problem des Rammpfahls.* Geiss. (78) Dec. 14.
Neues im Deckenbau. W. Daude. (78) Dec. 14.
Das Mischen des Betons. M. Marcichowski. (78) Serial beginning Dec. 14.
Ueber den Einfluss von Lokomotivgasen auf frischen Mörtel. E. v. Willmann. (78) Dec. 14.
Anforderungen an Krankenhausbauten in ärztlich-administrativer Beziehung. Eugen Hofmokl. (53) Dec. 15.

Water Supply.

The Hydropulsator.* Carl Frederick Dietz. (8) Oct.
Loss of Head in Screw Pipe Elbows and Tees.* D. H. Daley, E. W. Schoder, Patterson Bain, Jr., and George J. Davis. (36) Dec.
Surge in a Hydraulic Stand Pipe—Experiment and Theory.* Irving P. Church. (36) Dec.
Mixing, Diluting or Contaminating Effects with Liquid Flow in Pipes.* Ernest W. Schoder. (36) Dec.
A Short Account of Some Purification Experiments with a Surface Water in Queensland, Australia. Hardolph Wasteneys. (28) Dec.
Has the Time Come for Double Municipal Water Supplies—One Naturally Pure, for Drinking and Cooking, the Other Denatured or Sterilized, for all Other Purposes? W. T. Sedgwick and H. P. Letton. (28) Dec.
Some Notes on Tropical Water Supply and a Study of Filtration at Panama.* Herman K. Higgins. (28) Dec.
Highway, Water Supply and Sewerage Work in Toronto.* C. H. Rust. (104) Dec. 1.
A New Reinforced Concrete Paper Mill.* (Hydraulic arrangement.) (96) Dec. 7.
The Operation of the Rock Island Filter Plant.* (14) Dec. 9.
Ships' Anchors and Submerged Pipe Lines.* (14) Dec. 9.
British-Canadian Power Company.* G. C. Bateman. (64) Dec. 12.

*Illustrated.

Water Supply—(Continued).

The Gravity Water Supply for Norway, Mich.—Details of Design, Construction Methods, and Unit Costs of Reinforced Concrete Standpipe.* L. R. Howson (Abstract from Reports, Ohio State Board of Health.) (86) Dec. 13.
Pipe Dipping Plant and Cost of Dipping.* E. C. Willard. (86) Dec. 13.
Report of a Duty Trial on the Six Million Gallon Pumping Engine at the High-Level Pumping Station of the Toronto Waterworks.* (96) Dec. 14.
Irrigation in Turkestan. Arthur P. Davis, M. Am. Soc. C. E. (Abstract of paper read before the Nat. Irrig. Cong.) (13) Dec. 14.
The Colorado River Silt Problem, the Dredge *Imperial* and Irrigation in Imperial Valley, Cal.* F. C. Finkle. (13) Dec. 14.
A Test of Watertightness of Concrete Tunnel Lining Under High Head.* C. Raymond Hulsart, Assoc. M. Am. Soc. C. E. (13) Dec. 14.
Water Turbines.* A. S. Ostreicher. (Abstract of paper read before the South African Inst. of Engrs.) (47) Dec. 15.
Building the Gold Mountain Dam.* F. A. Post. (103) Dec. 16.
The Location and Design of Conduits on the Los Angeles Aqueduct, Description of Method for Determining Economical Gradient.* (14) Dec. 16.
The Municipal Water Softening and Purification Plant at Georgetown, Kentucky; Description of the Design and Operation of Works for Treating 750 000 Gallons of Polluted Spring Water Daily.* John K. Hoskins. (14) Dec. 16.
Irrigation Developments in the United States. F. H. Newell. (14) Serial beginning Dec. 16.
A New Method for Determining Economical Pipe Diameters.* Frank H. Carter. (14) Dec. 16.
The Coleman Hydroelectric Development on Battle Creek, California, a 20 000-h.p. Plant Supplied by Ten Miles of Earth Canal, Recently Added to a System Combining Four Plants.* (14) Dec. 16.
State Supervision of Dams and Reservoirs. Frank P. McKibben. (14) Dec. 16.
Grouting the Porous Foundations of a Dam.* (13) Dec. 21.
Tests of Centrifugal Pumps. (For Irrigation.) (96) Dec. 21.
A Pumping and Irrigation Chart.* S. N. Arnold. (13) Dec. 21.
Operation of Water Purification Plants. (Abstract of Report of the Chief of Bureau of Filtration, Philadelphia.) (96) Dec. 21.
The Humphrey Pump and Compressor.* William Young. (96) Dec. 21.
The Gullspang Hydro-Electric Power-Station, Sweden.* (11) Dec. 22.
A 40-Foot Earth Dam at Dallas, Texas; Methods and Cost of Creating a 7 000-000-Gallon Reservoir on White Rock Creek.* Eugene Couch. (14) Dec. 23.
The Hydroelectic Development at Bonny Eagle, Maine.* (14) Dec. 23.
The Cannon Falls Hydro-Electric Development.* (19) Dec. 23.
Calgary Hydroelectric Plant.* (27) Dec. 23.
Present Position of the Question of Water Supply. Gärtner. (Paper read before the German Assoc. of Gas and Water Engrs.) (66) Dec. 26.
Sterilization of Drinking Water by Ultra-Violet Rays. Courmont and O. Bujwid. (Papers read before the German Assoc. of Gas and Water Engrs.) (66) Dec. 26.
The New Waterworks for Skegness.* Percy Griffith, M. Inst. C. E. (Paper read before the Inst. of Water Engrs.) (104) Dec. 22; (66) Dec. 26.
Some Methods and Costs of Irrigation Construction on the Rock Creek Conservation Co.'s Project at Rock River, Wyoming.* W. D. Rohan. (86) Dec. 27.
The Ozone Water-Purification Plant at St. Petersburg, Russia.* (13) Dec. 28; (12) Dec. 1.
A Metal Flume without Cross-Ties.* (13) Dec. 28.
Power from Italian Mountain Streams at Heads from 656 to 2 985 ft.: The Adamello Development.* C. A. Tupper. (13) Dec. 28.
Hydroelectric Energy for Irrigation.* (27) Dec. 30.
An Inverted Siphon on the Orland Irrigation Project. (14) Dec. 30.
Studies of Special Methods of Water Purification. (14) Dec. 30.
The Prevention of Water Waste in Washington. (14) Dec. 30.
Filtration Results at Reading. (14) Dec. 30.
Grouting the Concrete Lining of the Rondout Pressure Tunnel.* Herman L. Wittstein. (14) Dec. 30.
Treatment of the Foundation for the Power House and Dam, Hales Bar, Tennessee River.* C. H. Tisdale. (100) Jan.
Reclamation and Conservation of the Alluvial Lands in the Upper Mississippi Valley, Now and Formerly Subject to Overflow.*. Charles W. Durham. (86) Jan. 3.
A Reinforced Concrete Railroad Water Tank 187 Feet High.* (86) Jan. 3.
Essai d'une Alimentation Générale d'un Groupe de Communes de la Banlieue de Liège par les Eaux de la Berwinne Hesbignonne et de l'Ourthe Souterraines Captées Respectivement à Paifve et à Angleur.* Ed. Detienne. (30) Dec.
La Déferrisation des Eaux par le Procédé Reisert Peter.* M. Bousquet. (33) Dec. 2.
Die Wasserkräfte Schwedens und deren Ausnutzung.* A. Oelwein. (53) Dec. 1.
Der Willcocks'sche Plan für die Bewässerung von Mesopotamien.* (51) Dec. 16.

*Illustrated.

Waterways.

Acids in the Monongahela River.* Thomas P. Roberts. (58) Nov.
The Panama and Erie Canal Locks—A Contrast.* Day Allen Willey. (10) Dec.
The New Ship Canal and Locks at Sault Sainte Marie.* James Cooke Mills. (10) Dec.
The Uses of the Great Lakes. Gardner S. Williams, M. Am. Soc. C. E. (13) Dec. 14.
Recent Flood Conditions on the Cedar River near Seattle, Wash.* George Holmes Moore. (13) Dec. 14.
A Reinforced-Concrete Wharf at Balboa, Canal Zone.* (From Annual Report, Isthmian Canal Comm.) (13) Dec. 21.
Protecting River Banks with Wire Netting and Gravel. (14) Dec. 30.
Progress of Work on the Panama Canal.* (46) Dec. 30.
Dredging at Muscle Shoals Canal with a Ladder Dredge.* A. D. Edwards. (100) Jan.
Report on Physical Characteristics of European Seaports.* Chas. W. Staniford, M. Am. Soc. C. E. (100) Jan.
River and Harbor Improvements: Progress and Needs in the United States, 1911. William H. Bixby. (Paper read before the National Rivers and Harbors Congress.) (100) Jan.
Los Angeles Harbor. Amos A. Fries. (100) Jan.
New Ore Dock at Two Harbors, Minn.* (15) Jan. 5.

---

*Illustrated.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONTENTS

PLATES

For Index to all Papers the Discussion of which is current in *Proceedings*, see the end of this number.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROBLEM OF THE LOWER WEST SIDE MANHATTAN WATER-FRONT OF THE PORT OF NEW YORK.

By B. F. Cresson, Jr., M. Am. Soc. C. E.

To be Presented February 21st, 1912.

Many municipal problems confront New York at the present time, and none is more pressing than that of the organization of the lower Manhattan water-front on the North River. The present congestion of growing business, the demand from all classes of carriers for additional water-front facilities, the coming of larger passenger steamships, and the generally unrelated use of this water-front, demand immediate consideration of the conditions, and the formulation of a policy toward which reorganization should grow.

The lack of public interest and knowledge of conditions, together with the trade rivalries of the carriers, make it most difficult to determine on a plan and policy. The problem largely involves economic conditions and commercial necessities, and, in this paper,

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

an endeavor will be made to describe briefly these conditions and necessities and indicate in general terms a plan for relief.

Much has been written concerning the adequacy of the terminal facilities and the excellence of the administration and control of the greater seaports of Northern Europe, and, in formulating a plan and policy for New York, what has been done in those seaports should be carefully studied.

The harbor of the Port of New York is not lacking in natural advantages, and, in comparing it with the important harbors of Northern Europe, one of the impressive features is the available space for almost indefinite expansion, provided it is properly organized. Situated directly at the entrance to the sea, it has an excellent channel, is amply protected from the sea by the comparatively narrow passageway between Fort Hamilton and Fort Wadsworth; and the wide expanse of the upper bay, which contains much shallow water, is capable of being enlarged for commerce by dredging and by the construction of piers or basins.

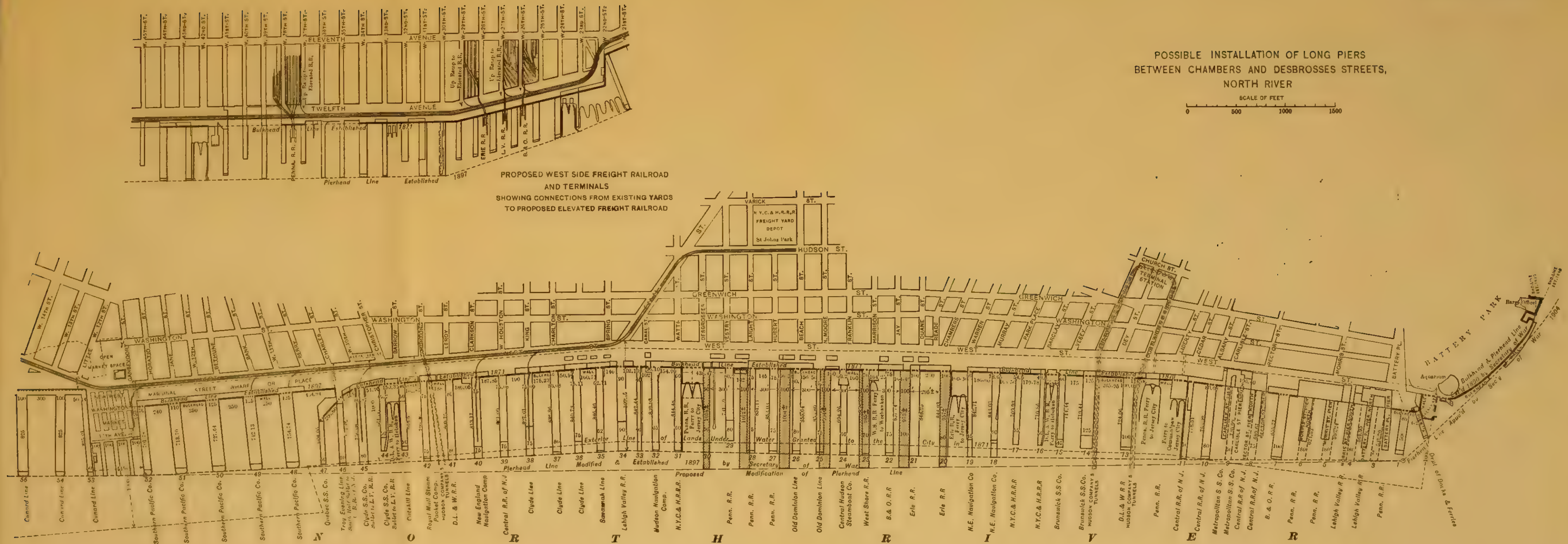
The tidal fluctuation is not great enough to interfere in any way with navigation from the open sea or from inland waters. The rivers are sufficiently wide to permit piers to be constructed at right angles, thus insuring economy in the use of the water-front by berthing ships end on, and not (as in many ports) requiring them to be docked against bulkhead walls and thus taking up a greater extent of water-front.

Greater New York has a water-front of about 450 miles, and if to this is added that of the New Jersey shore, including also Newark Bay, which are important parts of the port, it will easily be seen that it has a harbor which offers a wealth of opportunity.

At many European ports, practically all the water-front has been dredged from the mainland at great expense. It has been said that the things which come naturally are usually less prized and conserved than those which are obtained only by great labor; and the extravagant use of some parts of the New York water-front affords a remarkable contrast to the care and foresight with which European port authorities have organized and conserved the frontage which has been created for the most part artificially.

Properly controlled and organized, there is almost unlimited opportunity at New York for commerce to grow, whereas, in European

PLATE I.
PAPERS, AM. SOC. C. E.
JANUARY, 1912.
CRESSON ON
WATER-FRONT FACILITIES,
NORTH RIVER, NEW YORK CITY.



ports generally, additional room can be obtained only by dredging farther inland, and it appears that there must be a limit to this growth owing to the congestion which already exists in the comparatively narrow rivers leading to the sea.

In many European ports, the tidal fluctuation is so great as to make wet docks a necessity, that is, the port itself is constructed back from the river, access thereto being through locks, and usually only at high water. This causes very expensive construction and more or less complicated operation.

New York is already the greatest port in the world, in its volume of commerce, and when the Panama Canal and the New York State Barge Canal are opened, a still greater volume will naturally seek accommodation there. Being the natural meeting point of both rail and water transportation lines, facilities for the interchange of freight and passenger business on a very large scale must be anticipated.

The responsibilities of New York as the principal port of entry of North America are very great. Liverpool is the home port of the Cunard and White Star Lines, London of the Atlantic Transport Line, Havre of the French Line, Antwerp of the Red Star Line, Rotterdam of the Holland-America Line, Bremen of the North German Lloyd, and Hamburg of the Hamburg-American Line. While, of course, these great companies send ships to all parts of the world, their very best and largest vessels come to New York, and there it is the duty of the authorities to provide facilities which will give as much convenience as possible.

Practically every important railroad in North America has a terminal in New York. Those not having their rails physically either in New York or New Jersey, have as their connecting links the coastwise steamships.

If the supremacy of New York as a port of entry for the United States for passengers and high-class freight is to be maintained, there must be proper organization in order to increase its capacity as a port of entry and exchange for coarse freight, and make provision for industrial as well as commercial development.

Very little has been done constructively in the last few years, but certain conditions have now arisen which make prompt action necessary. At present there is congestion at only one section of the water-

front, and this is at the most desirable locality, namely, along the west side of lower Manhattan.

Presentation of the Problem.

There are a number of factors which make the problem of the reorganization of the lower Manhattan water-front difficult, and it is necessary to take them all into consideration to determine intelligently on the plan which best meets all conditions. The principal factors may be stated as follows:

1.—The desirability of docking the large transatlantic steamers at the lower Manhattan water-front;

2.—Provision for longer steamships;

3.—The railroad occupation, and its already congested condition;

4.—The dangerous, inadequate, all-rail connection of the New York Central Railroad;

5.—Congestion;

6.—The general increase in the commerce of the port.

All these factors are involved in the problem, and it must be looked at, not from the point of view of any individual carrier, but from that of the commercial welfare of the City and of the country as well.

The business interests using the water-front are shown by Table 1, the large proportion occupied by the railroads being evident.

TABLE 1.—Business Interests Using the New York Water-Front.

	From north side of Pier new 1 to 125 ft. south of Pier new 48, 11 780 ft. = 2.23 miles.	From north side of Pier new 1 to north side of West 30th Street, 20 658 ft. = 3.91 miles.
Transatlantic steamships	1.4%	17.5%
Coastwise steamships	15.6%	24.3%
Railroads	47.9%	30.8%
Hudson River boats	5.3%	3.0%
Sound steamers	10.0%	5.7%
Ferries	9.5%	7.8%
Open wharfage	4.3%	3.9%
Miscellaneous: coal, ice, dumps, oysters	5.8%	6.9%
Recreation piers	0.2%	0.1%

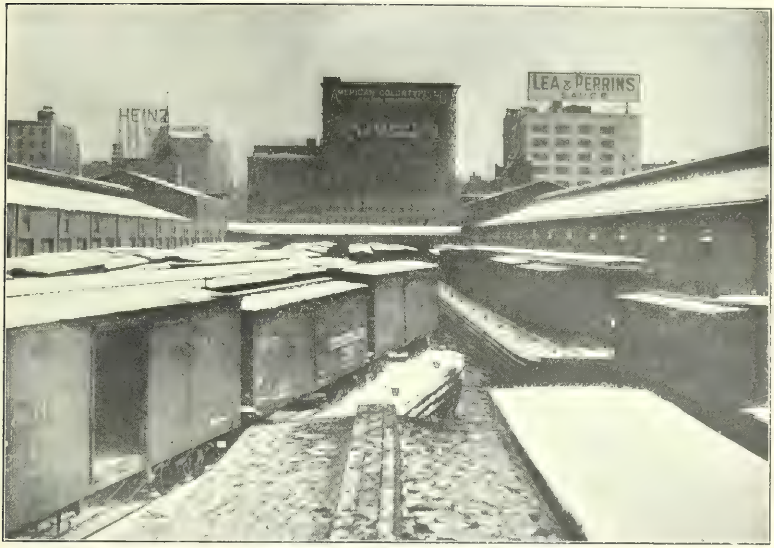


FIG. 1.—RAILROAD CARS ON CAR FLOATS IN SLIPS IN MANHATTAN.

FIG. 2.—FREIGHT CONGESTION IN A NORTH RIVER RAILROAD PIER.

Passenger Steamship Terminals.

As a terminal for the transatlantic service for passengers and some high-class freight, no part of the harbor is as desirable or as convenient as the lower Manhattan section, because of its proximity to the sea and the fact that it is in the heart of the business, financial, railroad, and hotel districts. The traveler coming directly to Manhattan does not have the inconvenience and difficulty of transferring from some other part of the harbor to the central district, and it is to this district that practically all travelers desire to come. Of course, long piers could be built in South Brooklyn and Staten Island to accommodate large passenger steamships, but, as an officer of one of the transatlantic lines has emphatically stated, the same reasons which impelled the New York Central and Pennsylvania Railroads to spend millions in establishing stations in the center of Manhattan make it desirable that the leading steamship lines have termini as near as possible to the same district. The desirability of retaining this business in Manhattan, therefore, is manifest because of the mutual advantages to the City and the steamship lines, and applications are on file at the Dock Department for many additional piers for steamship service.

Terminals for Ships of the "Olympic" Class.

The necessity of providing accommodation for the larger steamships now building for this port is very great. When the S. S. *Olympic* was nearing completion, an application was made to the Secretary of War for the extension of the pierhead line in lower Manhattan, so that the new Chelsea steamship piers between 12th and 23d Streets might be increased by 100 ft., making them 925 ft. long, in order to accommodate this vessel, which has a length of 882½ ft. There is no pier in lower Manhattan long enough to accommodate this ship, except by extending the pier farther into the river or by dredging inland. It was only after the urgency of the immediate requirements had been shown that temporary permission was given for two years by the Secretary of War for the extension of two of the Chelsea piers, and this was done with the distinct understanding that within that period the City must commit itself to a plan which would make provision for long ships, without permanent encroachment on

the fairway of the North River, particularly in the Chelsea section, where the river is narrowest.

There are now nearing completion and under construction a number of other ships of the *Olympic* class, and even larger. Every one of these ships is built for the New York trade, and application has been made to berth them in lower Manhattan. Nearly a year has passed since the temporary extension was granted, and, therefore, it is now absolutely necessary to face this situation squarely.

The City owns and has possession of the property on the North River between Gansevoort and Little West 12th Streets, and this is practically the only property on the lower Manhattan water-front which is under its control. It is set aside as a market, handling general supplies, refrigerator goods, etc., and receives nothing from the water-front. Formerly it was situated in front of the present Washington Market, between Fulton and Vesey Streets, but the necessities of commerce compelled its removal, and it was located at its present site, from which it must again be moved. The water-frontage of this market is occupied as an oyster basin, and there are three small piers utilized mostly as open wharfage.

The necessity of using this space between the two finest steamship installations in the harbor as a market for oysters, poultry, and meats, is not apparent. Application has already been made looking toward legislation for the removal of this market, and, when this is accomplished, a basin may be dredged inland creating berths for two ships 1 000 ft. in length. These, while not giving a permanent remedy, would afford immediate relief, and, by keeping them in the control of the City, could probably take care of the larger ships until better arrangements could be made.

In the pierhead line between the Battery and Gansevoort Street there is a bow which, if straightened out, would permit of constructing piers 1 000 ft. long in the vicinity of Canal Street without digging inland (Plate I). It is believed that the Secretary of War will at least consent to straightening this line, and, if the railroads which now occupy much of this section can be accommodated in any other manner, a very fine series of steamship piers 1 000 ft. long can be created in a locality where it seems most desirable.

Diagonal piers have been considered, but there appear to be many objections to them. At ebb tide a steamer, backing out from its berth,

is compelled to turn more than 90° while floating down the river, and, with diagonal piers, under similar tidal conditions, would back into the river practically pointed up stream. Piers are now built at right angles to the river, and considerable space would be lost at the junction between the straight and diagonal piers.

It is suggested that between 23d and 30th Streets long piers can be created by dredging inland, but this could not be done without

POSSIBLE INSTALLATION OF LONG PIERS BETWEEN
44th AND 50th STREETS, NORTH RIVER

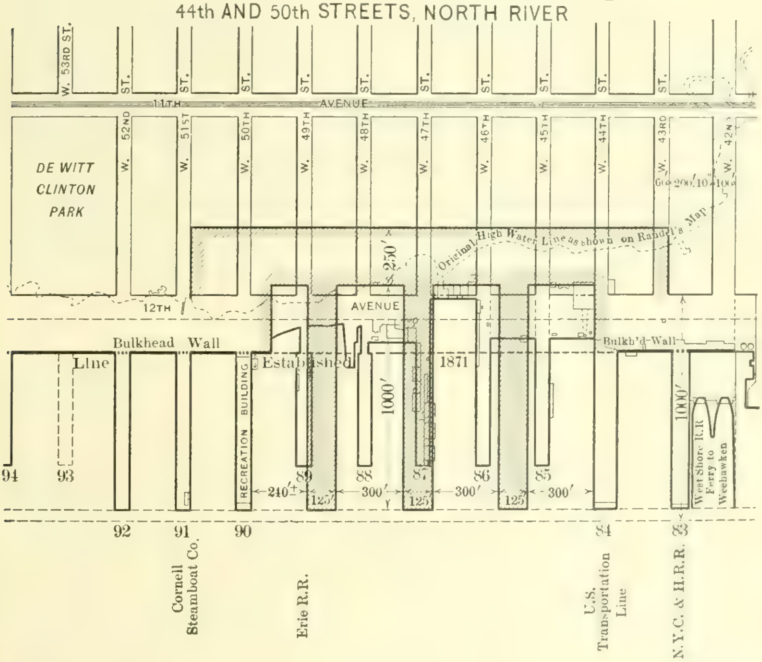


FIG. 1.

disturbing water-front leaseholds and upland which is valuable for railroad terminal purposes in this district, which would be very undesirable.

Fig. 1 is a study of a scheme for long piers between 44th and 50th Streets. In this locality, the City owns the street ends, but otherwise all the bulkheads are privately owned; and these bulkhead rights would have to be acquired, as well as the upland, in order to make such an improvement.

In accordance with a terminal plan for the future, as well as the present, the Department of Docks has recommended that long piers for steamships of the first class should be progressively provided to the south of the Chelsea district, instead of to the north. This will leave river navigation freer and will better permit of railroad terminal extension in the future. If temporary needs should be considered the controlling factor, however, the district between 44th and 50th Streets, which is not now required for railroad terminal purposes, might be utilized.

It should not be the policy of the City to build expensive bulkhead walls and façades to any piers which are now to be constructed for long steamships; but it should be made as easy and inexpensive as possible to extend slips inland, should the coming of even larger ships require this. The Chelsea piers, with their expensive bulkhead walls and façades, were scarcely finished when they were found to be too short to accommodate the ships which the lessees of these piers had under construction.

It is impossible to foresee the limiting length of ocean steamships, though it appears to be certain that there must be a limit. It seems unlikely that they will be built of much greater draft than at present, inasmuch as the channel depth at practically all harbors is sufficient only for the present draft. It is possible, however, to add to the tonnage of ships by increasing their beam without increasing their draft, and it does not seem impossible to consider that there will be ships even longer than those now constructed. The limiting factor appears to be an economic rather than a physical one. Large ships are very expensive to build and to run. If they could be utilized to their maximum capacity at all times, they would no doubt be very profitable, but it seems unlikely that they will run at maximum capacity, except in certain seasons, and the matter of economy, it is believed, will determine the limiting sizes. The use of the finer ships for cruising purposes in the off season probably could not include these larger vessels.

Railroad Freight Terminals.

Explanation is necessary as to the railroad occupation in lower Manhattan. Railroad cars are placed on carfloats in New Jersey and in the early morning are towed to the Manhattan water-front, where

FIG. 1.—CONGESTION OF TRUCKS ON NORTH RIVER MARGINAL WAY.

FIG. 2.—CONGESTION OF TRUCKS AND FREIGHT ON THE NORTH RIVER MARGINAL WAY.

they occupy the slips between piers. Freight from these cars is discharged on the piers, from which it is carted on trucks; the cars are then reloaded with freight delivered by trucks at the bulkheads. This means that a floating railroad yard passes from New Jersey to Manhattan every day, remains in Manhattan during the day, and is floated back to New Jersey in the evening. There are usually from 1 500 to 2 000 freight cars daily standing in the slips in lower Manhattan.

The freight which is handled in this manner consists mainly of food supplies and raw materials for fabrication and consumption in Manhattan itself, and, on account of the inadequate space which the railroads now have, as much freight as possible is diverted from Manhattan. Plates II and III show the method of railroad occupation, and the congestion of freight and trucks incident thereto. The existing condition, therefore, is that, with the water-front very much congested, there is a continued demand for more facilities by the railroads, and under the present methods, this could only be supplied by the further exclusion of steamships. The freight business which the railroads do with the steamships is handled mostly by lighters from New Jersey directly to the ships alongside, or to the steamship piers.

The piers which the railroads now occupy were not for the most part designed for railroad use, and it is no doubt possible that others could be designed which would have a greater capacity for handling freight. It does not seem that this would solve the problem in the North River, because, if the capacity of the pier is increased, the congestion of trucks along the marginal way would be correspondingly increased, and this congestion is one of the principal factors in the problem.

In practically all European ports, the water-front is under more complete control by the municipality than in New York, and mechanical devices for freight handling are everywhere in evidence. In New York, however, there is very little in the way of mechanical appliances, particularly for handling package freight. It would be difficult to design a system of carriage which could handle this freight quickly and cheaply, coming as it does in all shapes and sizes. An earnest effort is now being made by the Department of Docks to find some system which will decrease the expensive hand trucking now necessary. European freight cars differ from those in America, as they are

smaller in size and capacity, and generally have the top open—canvas covers being used extensively. It is much easier to devise means for placing freight in an open car than in an American box car.

At the Port of New York there are several private companies which are admirably organized and operated, and the fact that they, with complete control over their water-front, factories, warehouses, and connecting railroads, have not applied mechanical devices more extensively seems to indicate the difficulty of handling package freight except by hand, horse, or motor truck.

Surface Tracks of the New York Central Railroad.

The New York Central Railroad has the only all-rail connection to lower Manhattan. The line follows down the westerly water-front from Spuyten Duyvil as far as 60th Street, and reaches a terminal at St. John's Park, bounded by Varick, Hudson, Laight, and Beach Streets, by surface tracks on Eleventh Avenue, Tenth Avenue, West Street, and Canal Street.

This all-rail connection, though very inconvenient, dangerous, and expensive, is of great value to the City, and, by reason of its existence, a strong competitive influence is exerted over the other rail carriers. There has been agitation for cutting these tracks at 60th Street or at 30th Street and requiring the New York Central to carry on its business in lower Manhattan by carfloats in a manner similar to that followed by the other railroads, but it is believed that it would be unfortunate to adopt such a plan, in view of the existing congestion on the water-front and the value to the City of this useful and competitive facility. In addition, it is questionable whether these tracks could be cut without the approval of the New York Central, or without providing a relocation for them.

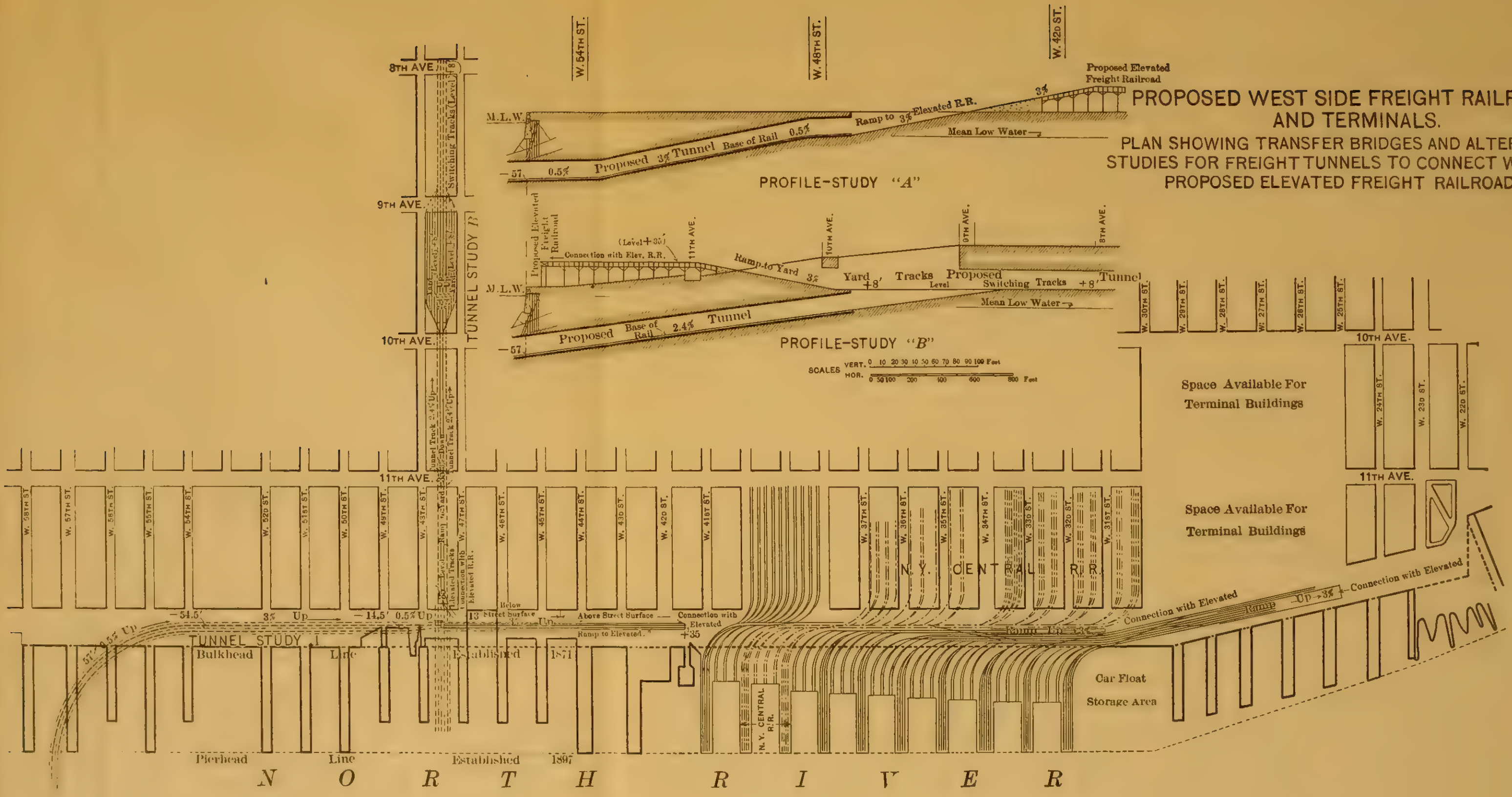
New York Central's Plans.

Under recent legislation, the New York Central Railroad has submitted plans to the Board of Estimate and Apportionment showing its desired improvement. Above 60th Street, these plans show additional tracks, and types of covering in front of park property. Below 60th Street, they show an elevated railroad, four tracks as far as 30th Street and two tracks as far as Cortlandt Street, with an elevated spur connection through Canal Street to an enlarged St.

PLATE IV.
PAPERS, AM. SOC. C. E.
JANUARY, 1912.
CRESSON ON
WATER-FRONT FACILITIES,
NORTH RIVER, NEW YORK CITY.

PROPOSED WEST SIDE FREIGHT RAILROAD AND TERMINALS.

PLAN SHOWING TRANSFER BRIDGES AND ALTERNATIVE STUDIES FOR FREIGHT TUNNELS TO CONNECT WITH THE PROPOSED ELEVATED FREIGHT RAILROAD.



John's Park Terminal, necessitating an elevation of the Ninth Avenue Passenger Elevated Railroad over the proposed freight road, and a general electrification of the entire line.

In the district below 60th Street, the plans call for permanent overhead rights to be acquired by the New York Central Railroad, its present surface rights to be surrendered. To grant these exclusive rights to this railroad would give it such an advantage over the other roads now doing business at this port that it would be likely to give it a monopoly to the disadvantage of the other roads and the City's commerce.

The congestion of freight on the piers, bulkheads, and marginal way, and of trucks on the latter is shown by Plates II and III. The expense to the railroads of maintaining these terminals is great, and, to the merchant, it is usually much greater than the freight rates, because of truckage delays.

General Plan for Reorganization.

Calvin Tomkins, Assoc. Am. Soc. C. E., Dock Commissioner, in his studies of the problem with the writer and the engineers of the Dock Department, believes that another method can be found for carrying on the railroad business, namely, by conducting the joint railroad business over a public elevated railroad operated electrically.

A subway has been considered, but it is not thought that it can be constructed economically or operated satisfactorily on the Manhattan water-front. There is little objection to a subway or tunnel for freight purposes as a connecting link between terminals, but, as a distributing line with sidings leading therefrom, the operation would be very difficult and dangerous.

The New Jersey roads, by transfer bridges such as they use in New Jersey, can make a connection with a municipal elevated railroad in the district between 30th and 40th Streets, and from it can discharge their cars and freight into terminals anywhere along the easterly side of West Street, with opportunity for expansion, and the New York Central can have access to it directly from its yard at 60th Street.

With this railroad built and under the control of the City, and available for use by all the railroads, it is believed that conditions will be created which will enable the City to devote to maritime

commerce a large portion of the water-front which is now given over to railroad carfloats.

Studies have been made for transfer bridges at the lower end of Manhattan connecting with the elevated railroad. This is entirely feasible, but it is thought that the conflict of movement on the elevated railroad in opposite directions during the rush periods will make it difficult to operate. However, connection in lower Manhattan can easily be made.

There is no disputing the fact that the railroads terminating in New Jersey, which are compelled to depend on carfloats at present, will be at a disadvantage with the New York Central, but the disadvantage would be much greater if the New York Central were permitted to monopolize this proposed elevated railroad.

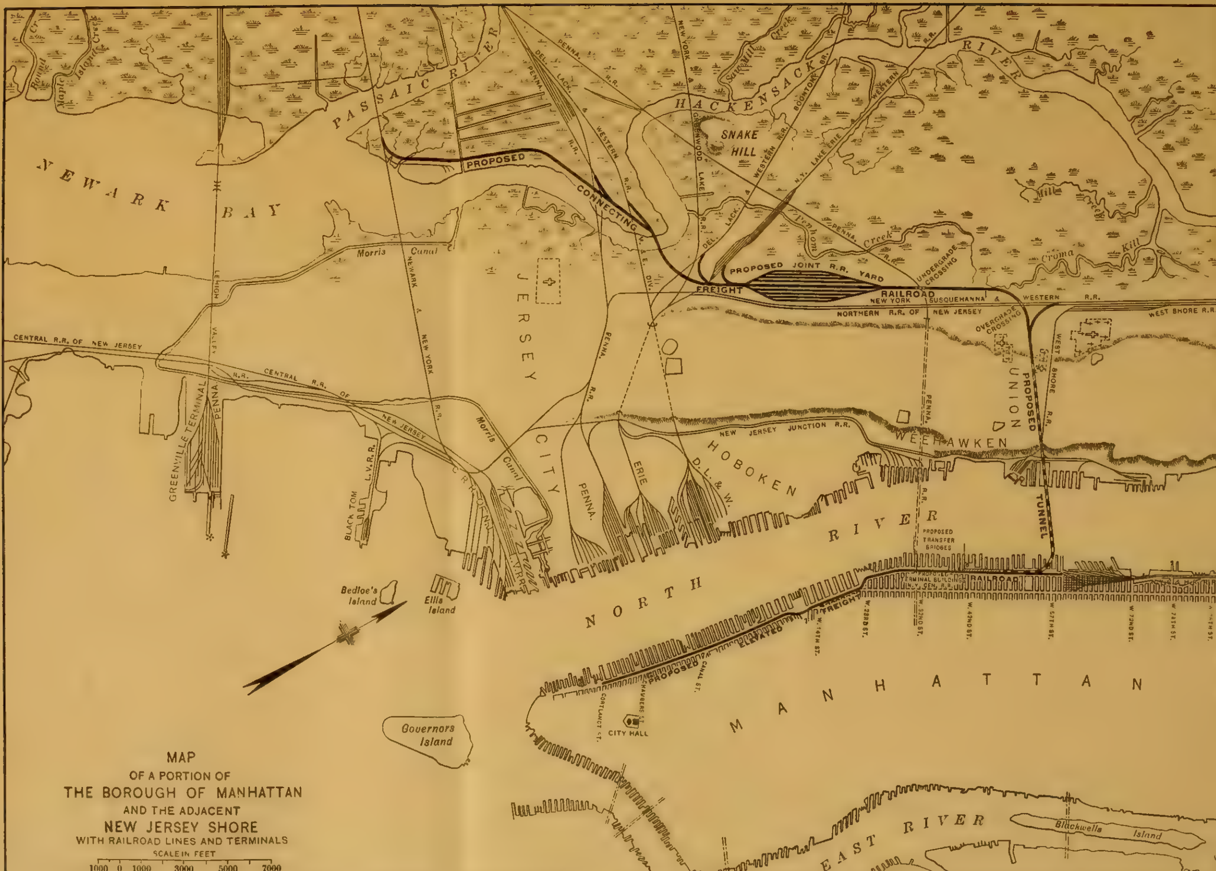
The connection by transfer bridges, whereby the New Jersey roads can have access to the elevated railroad, has been worked out with great care, but is capable of modification in almost any respect. There is nothing complicated about the operation, or which is not now done at many points in the harbor. The difficulties to be overcome appear to be lack of speed, expense of operation, and congestion. The new arrangement will no doubt require more time between the terminals on the easterly side of West Street and the bridges in New Jersey, but it is believed that, by arranging a proper schedule, shipments can be made during a large part of the day, thus getting many cars into New Jersey much earlier than at present.

The cars on carfloats now form a floating yard in Manhattan which must be maintained as a complete yard in order that the runways on these floats may be utilized until the closing time in the afternoon.

As to expense, the railroads are now operating under great congestion and expense in New York in improperly organized terminals. They are subject also to very heavy rentals for piers and bulkheads, and the carfloats which they now use have but two tracks and are of small capacity. With proper organization, the elimination of expensive pier rentals, and the provision of proper floating units, it is believed that they could afford to pay for service over the distributing elevated railroad.

As to congestion at the transfer bridges, it should be remembered that at present, in a single slip between two piers, as many as twelve

PLATE V.
PAPERS, AM. SOC. C. E.
JANUARY, 1912.
CRESSON ON
WATER-FRONT FACILITIES,
NORTH RIVER, NEW YORK CITY.



carfloats are placed every morning and removed every evening, and there does not appear to be any great difficulty or congestion in this movement. If all the railroad business cannot be done by carfloat transfer bridges between 30th and 40th Streets, at least there is capacity for a large part of it. The necessity for expensive yards in New York for assorting cars does not exist, as the trains which are destined for certain terminals in Manhattan now occupying the water-front, but which then would be located on the easterly side of the marginal way and be served by the elevated freight railroad, can be made up in New Jersey, as at present.

The plan in general for carfloat transfer to the elevated railroad has not been accepted by any of the railroads, and this is perhaps natural in view of the disinclination to operate jointly, and the fear that any admissions may be used as an argument for forcing them from the water-front to the elevated railroad. The railroads probably do not think it desirable that the water-front which they now occupy should be surrendered to coastwise steamships which, as previously stated, are connecting links of other railroads terminating at southern ports, and competitors of the railroads coming to Jersey City. This business, the New Jersey railroads suggest, should be diverted to other parts of the harbor; but, considering all things, it is safe to believe that the New Jersey railroads will oppose granting to the New York Central permanent exclusive franchises and rights on the marginal way.

The foregoing plan for connection from the New Jersey railroads to the proposed elevated railroad by carfloats and transfer bridges is not the best permanent solution of the difficulty.

Freight Tunnels.

It has been proved that tunnels for full-sized rolling stock can be built successfully under the North River. The final solution of this problem would include an all-rail connection from a joint assembly and classification yard in New Jersey to the elevated railroad in Manhattan, thus entirely doing away with the necessity for car transfers by carfloats. With this tunnel connection, a very much more economical system of freight distribution in Manhattan can be had with the use of a very small water-front.

Plate IV shows a study for an all-rail connection between New York and New Jersey from the general classification and assembly yard in New Jersey, with spurs leading to all the New Jersey roads, so that all would have access to the yard. From this yard, by tunnel, a connection is shown to the proposed elevated freight railroad.

The small plan on Plate I shows four existing railroad yards in Manhattan between 25th and 39th Streets. Considerable business is done in these yards with the use of a very small extent of water-front, and it will be possible immediately to make a connection to the elevated railroad from these yards, as indicated on this plan, so that, in the early stages of the undertaking, the railroad will be available, not only for the New York Central, but also for the Baltimore and Ohio, the Lehigh Valley, the Erie, and the Pennsylvania Railroads.

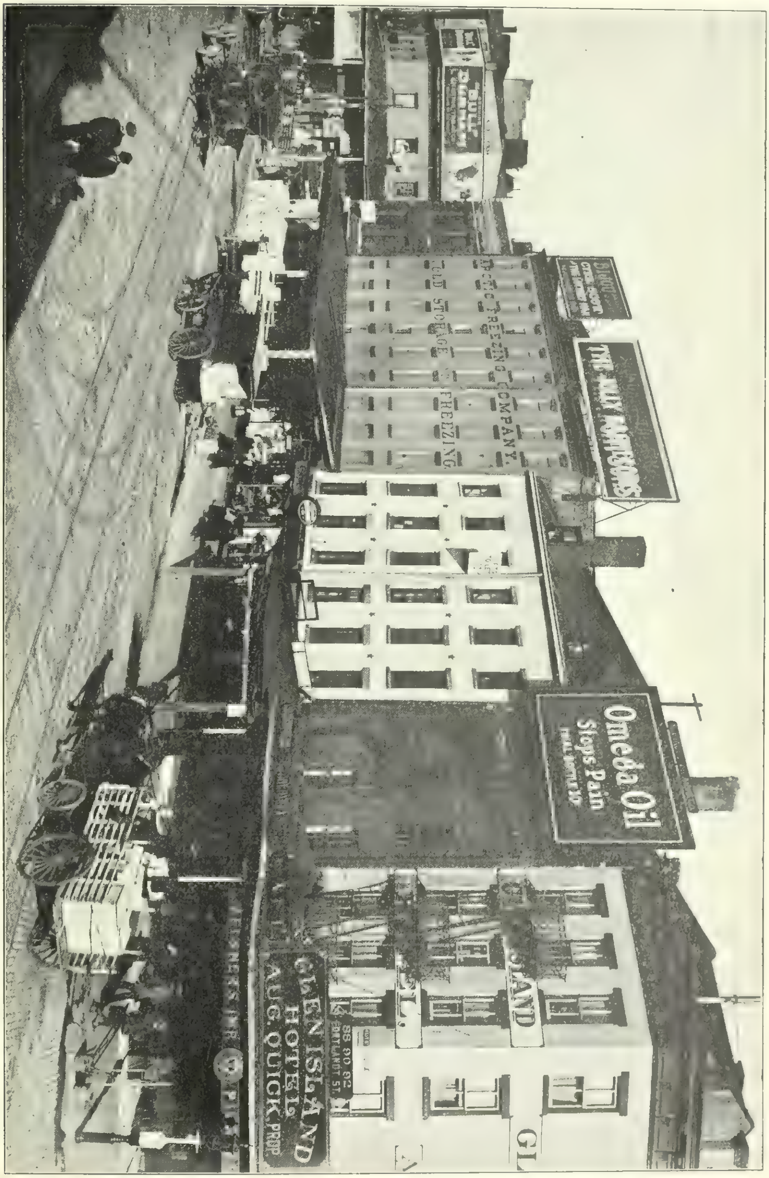
Plate V shows a suggested arrangement of transfer bridges, ramps, and tunnel connections, laid out so that the New York Central may not be prohibited from properly using its proposed terminal north of 30th Street. This general plan would have the effect of giving the City an adequate freight service by the New York Central, and would cause the removal of the tracks from the surface below 59th Street. It would develop terminals on the practically unused property on the easterly side of West Street. It would create a demand for service by the other roads, and, in supplying this demand, would gradually move the railroad cars from the water-front and afford opportunity for expansion on property now used as indicated on Plate VI, which property would be available on the lower floors for freight terminals and on the upper floors for warehouses, factories, and other commercial uses.

The method of construction of the proposed elevated railroad, the method of operation and control, and other details, can be worked out with the assistance and co-operation of the railroads.

By creating better facilities than now exist at the center of the island, there would be a tendency to draw from that section a large part of the business carried on in a very congested way and subject to great expense for trucking; and, by providing another method in which the railroads can carry on their business, it will make available the lower Manhattan water-front for steamship purposes.

In almost every other harbor, the railroads carry on their business

PLATE VI.
PAPERS, AM. SOC. C. E.
JANUARY, 1912.
CRESSON ON
WATER-FRONT FACILITIES,
NORTH RIVER, NEW YORK CITY.



CHARACTER OF MAJORITY OF BUILDINGS ON EASTERLY SIDE OF WEST STREET, MANHATTAN.

with the City in a district away from the water-front, and that principle should be followed here under the plans proposed. One of the most important features of these plans is that it can be carried out without disturbing existing conditions. It should not be the plan to draw manufacturing to Manhattan or to develop Manhattan at the expense of other parts of the port. Studies have been made and reports published showing plans for the development of practically all parts of the harbor.

Under a recent constitutional amendment, Dock Bonds which are invested in self-sustaining enterprises are eliminated from computation in fixing the debt limit of the City, and are available for further investment. The Dock Bonds which will become available in this manner, it is estimated, will amount to $70 000 000, and it should be the City's policy to invest this fund so that it will immediately or very soon earn its interest and sinking fund charges and in turn be removed from the debt limit, thus giving the City a working capital for dock improvements.

The plan of the elevated railroad is not a new one, and many others have been considered, but that outlined herein appears to meet nearly all the conditions. Criticism of the general principles of this plan should be constructive in order to be of any value. The difficulties of operation and organization are recognized, but this plan provides a solution, at least for some of them.

These plans have been worked out at the instance of Dock Commissioner Tomkins, and are the result of long study and intimate acquaintance with the features of the problem. In making the studies, details, and general plans, the Dock Department has consulted with various interests in the port, in order to obtain criticism from every source, and has had the aid and co-operation of William J. Barney, Jun. Am. Soc. C. E., Second Deputy Commissioner, Charles W. Staniford, Chief Engineer, S. W. Hoag, Jr., Deputy Chief Engineer, and R. T. Betts, Assistant Engineer, all Members of this Society, and the general staff of the Department.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE JUST VALUE OF MONOPOLIES, AND THE REGULATION OF THE PRICES OF THEIR PRODUCTS.*

By Joseph Mayer, M. Am. Soc. C. E.

Recent industrial development has produced a large number of enterprises, among them those supplying transportation, communication, light, heat, and power, which are to a considerable extent natural monopolies; that is, their products or services are sold at prices not governed by competition. Excessive prices have resulted therefrom. To secure fair prices to the public, various commissions have been established to control them, and many Court decisions have been rendered for the same purpose; but all these decisions have been insufficient to establish clearly the principles which should govern the determination of fair prices of monopolized products.

The Courts hold that a monopoly, if properly managed, is entitled to such prices for its products as will secure a fair profit on the just value of its property.

Thus far, no satisfactory method of ascertaining what is a fair profit and what is the just value of the property of a monopoly has been described by the Courts or commissions. The hopes and fears in regard to the probable future course of the Courts and commissions in their efforts to fix fair prices for the products and services of

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

monopolies have large influence on the current market value of their securities, and are a factor seriously disturbing the even course of business. Therefore it is of importance to establish the principles from which the fair prices of monopolized products can be reliably deduced, and this is the purpose of the following investigation.

The difficulty in regard to what are fair prices arose with the disappearance of competition. The prices arising from reasonable competition are considered fair and just by all Courts and commissions. Just or fair prices of monopolized products, therefore, are such as would rule under fair competition, fair competition being such as gives the value of the product to the producer. The necessity for regulation arises from the prevalence of such prices as will give to monopolized industries unfair profits, or profits larger than prevail in competitive industries at the same time and place.

Just prices, therefore, are such as produce in monopolized and competitive industries the same rate of profit. To determine fair prices, therefore, we must ascertain the rate of profit in competitive and in the various monopolized industries. Profit is the compensation of the owner of an enterprise.

The prices of industrial products are equal to the material costs, or the expenses of production plus the profit of the owner. The expenses of production of the same product are different in every enterprise: the profit of the owner, therefore, is different to the same extent. The profits of a business depend partly on the capital invested, but still more on the intelligence and skill used in its original design and in the management thereafter. The vastly different rate of profit, or ratio of profit to capital invested, which prevails in industrial enterprises, enlarges the scope of activity of the most successful managers, and removes the incompetent ones; it is the only standard by which the ability of a manager can be accurately tested; it destroys altogether many ill-planned enterprises, and forces the remodeling of others; it is the source of progress in all industry, as it is the incentive enforcing the adoption of radical improvements in methods of production with all their expense, risk, and trouble; it is the reward for intelligent and the punishment for incompetent management. Even for the maintenance of the prevailing standard of economic efficiency, it is absolutely necessary that the scope of the enterprises of least cost of production and largest profits

be constantly extended so that those of highest cost of production and smallest profit may be abandoned. The prevailing prices are equal to the cost of production plus the profit of the most inefficiently managed enterprises that succeed in existing, and the products of which are needed to make supply equal demand. Any regulation of prices which interferes seriously with this process of lowering the cost of production must lead, not only to stagnation, but to retrogression of economic efficiency. When higher than competitive prices are maintained in any industry, enterprises of exceptionally low standard of efficiency are thereby enabled to exist. The inefficient regulation of monopolies, permitting excessive prices of their products, therefore, often leads to a lowering of the standard of economic efficiency.

If the prices and profits of competitive enterprises are just, just prices for monopolized products must be such as will secure vastly different profits in different enterprises, according to the degree of intelligence used in planning and managing them. Any attempt to establish a uniform rate of profit on the physical valuation of the plant of monopolized enterprises, therefore, is radically wrong. Of two such plants of equal physical valuation, one may be that of a prosperous enterprise earning 20% dividends with just prices for its products, the other that of an enterprise on the eve of abandonment, because of ill-adjustment to the conditions of success. The value of one plant is not that of its parts, but can only be judged by its net earnings; that of the other is only a small fraction of its cost of reproduction less physical depreciation.

Since the profits of individual monopolized enterprises must remain vastly different to secure economy of production, the only profits which can and should be alike in competitive and monopolized industries are the average profits.

The prices of monopolized products or services, therefore, must be regulated so that the average profit of each monopolized industry is the same as that of competitive industries.

If it is practicable to ascertain the average profits of the various industries, this principle will enable us to judge the fairness, on the whole, of any definite proposed system of prices of monopolized products. It alone is quite inadequate to serve as a guide for creating such a system of prices. For this latter purpose it must be supplemented by a detailed study of the different industries in order to

ascertain the just differences between the prices of the same product in different places, or when produced under such different material surrounding conditions as are independent of the skill of the management of each enterprise. The difficulties of ascertaining the average profits of the various monopolized and of competitive industries are apparently so great that this problem must first be solved in order to ascertain whether the proposed system of regulation is practicable. An exact definition of the term "average profit" must precede any further discussion.

In any large enterprise, carried on through a long period, money (or products and services of a value which can be expressed in money) is invested at various times, and interest and dividends, or other moneys, are paid out to the owners, at other times, as compensation for ownership. What is the profit or rate of profit in this enterprise? For the sake of brevity, the term "profit" will often be used in this paper for "rate of profit," which latter alone concerns us here. The rate of profit, when constant, is the ratio of annual compensation for ownership to the money invested. It has the same meaning as the rate of compound interest secured on the investment.

The term "average annual profit" of an enterprise from its beginning to the present may be defined as the present value of all the receipts of the investors, divided by the sum of the present values of the average capital of each year. For determining the present from the past values, the rate of interest taken must be the same as the rate of profit. The percentage of profit is the rate of profit multiplied by 100. If we call x the percentage of profit, and make $y = 1 + \frac{x}{100}$, then the above definition of the percentage of average annual profit leads to the following equation:

$$\frac{\Sigma\, a\, y^n}{\Sigma\, A\, (y^m + y^{m-1} + \ldots + y^{m - m_1 + 1})} = y - 1$$

where a represents a sum received by the investors; n the number of years which have elapsed since it was received; $a\, y^n$ is the present value of the sum, a; and the whole numerator, $\Sigma\, a\, y^n$, is the sum of the present values of all moneys received by the investors. A is the average capital of a year; m is the number of years which have elapsed since the middle of that year; m_1 is the number of years the capital remained in the enterprise; the whole denominator is the sum

of the present values of the average capital of each year; and $y - 1$ is the rate of profit. The values of y and x can be found most readily by using compound interest tables; the calculation is simple, and is a purely algebraic problem which need not here be considered. The main difficulty lies in ascertaining, from the accounts of the corporation and other available sources, the correct amount of all the sums paid in, and received by the investors, with the dates of payment. If investors are executive officers, their salaries should be considered as expenses, not as compensation for ownership. Fees of directors are also expenses. Temporary loans made to the corporation are best not considered as part of the money invested in the corporation, and the interest on them is then part of the expenses. The rate of interest paid by a monopoly for temporary loans is not different from that paid by competitive corporations, and does not need regulation. Bondholders should not be considered as mere creditors; their compensation often largely depends on the success of the company. They must be regarded as investors; otherwise the amount of profit could be manipulated, and would largely depend on the amount of various kinds of securities issued. The interest going to bondholders must be considered as part of the profits, and the money paid in by them as part of the capital. The balanced average profit of several corporations is obtained by adding the numerators of the foregoing equation found for each of them and dividing this sum by the sum of the denominators for each of the corporations. With proper regulation of the corporations, which is required to secure the interests of the security holders, it will be possible in future to ascertain with reasonable accuracy all the facts needed to determine their average profit. The objection will be raised that the profit of a corporation is not what is paid out to bond and stockholders, but its net earnings. For the investor, the profits are what he receives divided by his investment, the investment being the amount paid to the company for his securities; and if the average profits as thus determined are—in the past, present, and future—the same in competitive and in monopolized industries, the investor is but justly treated, if he was in the company from its start. The public, it is true, pays for the net earnings, but if the investor cannot obtain more than a fair share of these net earnings, the public, with this system of regulation, will obtain in future what it misses at present. Furthermore, there is no

reason to assume that monopolies will accumulate net earnings more rapidly than competitive enterprises. The annual net earnings of a corporation are the increase in value of its property during the year. The definition alone is sufficient to show the extreme difficulty and complication in determining the actual, not the nominal, net earnings. Any regulation based on net earnings, therefore, would have a very uncertain basis.

Practically the same objection may be raised in another form by stating that the profits of the investor consist, not only of the money received from the corporation, but of this money and the increase in market value of his securities. The market value of the securities is an estimate of the present value of the future net earnings.

The investor cannot collect now these future net earnings; he can only transfer his claims to others. If future profits are justly regulated, the public need not pay to the investor more than what is fair, and it pays then nothing for any increase in market values that may occur.

It will hardly be denied that justice to monopolized industries would have been secured if the principle of equal average profits on the real capital invested in competitive and in monopolized industries had been enforced from the start; and that with proper regulation of all corporations, such as is necessary for the protection of the interests of the stockholders, it would have been practicable to ascertain with reasonable accuracy all the facts necessary for such regulation. With old corporations, however, it is now impossible to obtain these facts for the remote past; and, if it were possible, the attempt to make the average total profits in the past and future of the different monopolies and of competitive industries the same, by reducing future profits below the average in industries with excessive past profits, and increasing future average profits where past profits were low, would work grave injustice among the investors of the present.

The closest practicable approach to justice will be secured by making the average future profits of present and future investors in monopolized and competitive industries the same. This will be most nearly attained when the present market value of the stocks and bonds outstanding is considered as the present capital of the corporations. The future capital can then be obtained by adding all the moneys received in exchange for stocks or bonds sold.

Short-time loans and other liabilities of corporations are best not considered as part of the capital, and the interest paid on them not as part of the profits. With this modification, the proposed system of regulation becomes practicable, and can be introduced without material disturbance of the relative value of the securities of monopolies and competitive industries, and, therefore, without injustice to present investors. To obtain a fair market value of securities, eliminating a large part of the accidental changes due to manipulation and other momentary causes of fluctuation, the average value during a few years should be taken. For many securities, especially of small corporations, there is no real market, because there are no sales; in these the value can be approximately estimated from the dividends and interest received, unless they are new enterprises which have not yet obtained sales commensurate with the capacity of their plants. It is not necessary to ascertain the capitalization of all the corporations in a monopolized industry. The average profit resulting from any proposed system of prices in any monopolized industry may be ascertained with reasonable accuracy when the capitalization and the sums received by the investors are known for the bulk of the corporations engaged in this industry. Corporations in which the value of the securities is not ascertainable, therefore, may be omitted from the calculation without serious error. After present capitalization is ascertained, it will be easier, with proper regulation of the accounts of corporations, to determine closely future capitalization. The amount of dividends and interest obtained by the security holders will also be easily ascertained.

As all additions to capital can be closely estimated, the proposed method of regulation will give just returns on all new investments of capital in monopolized industries. It may be claimed that this amounts to legalizing, for all future time, the present often unfair charges for monopolized products. This is not so. Where the charges of monopolies are known to be unfair, the investing public is aware of the fact and knows that they may be reduced by Courts or commissions. The market value of the securities of such a monopoly, and to some extent of all monopolies, is thereby reduced. This market value is the estimate of the present value of the probable future profits, making allowance for probable future regulation of prices. To allow the same average profits on the market value of the

securities of monopolies and of competitive industries, therefore, is to allow to monopolies such profits as the public believes they will get, and means reducing their charges to the same extent as is, by the public, considered likely to happen. This is the closest practicable approach to justice. Absolute justice is impossible whenever injustice has been tolerated in the past and is then made illegal by a change of public opinion.

After having found a method of judging the justice on the whole of any proposed system of prices of the products of a monopolized industry, let us look at the method which must be followed in framing such a system. Let us take as illustration the gas industry. What we need is the just difference in the prices of gas of a given quality in different cities, and that in the prices of different qualities of gas. After we have these just differences we can frame a system of prices, starting with the existing prices in one city, which system is relatively just for different cities and different qualities of gas. If this system gives average profits in the gas industry, equal to the average profits in competitive industries at the same time and in the same place, it is not only relatively but absolutely just. If the profits are too high, all the prices must be lowered, without change in the differences; in the opposite case they must be increased. Just differences in price are those due to inequalities in the costs of production, caused by those differences in conditions which are independent of the degree of skill used in the design and management of the plants. In ascertaining the differences in cost of production, those methods of production must be assumed which are most generally used and therefore best known. Differences in cost of production due to either unusual skill or unusual incompetence of management must, in monopolized as in competitive industries, cause equal differences in profits and no difference in prices. Neglect of this principle and determining the just prices for individual enterprises by obtaining their costs of production and adding a standard profit would be disastrous to economy of production in all industries.

If, for a just regulation of prices, it were necessary to ascertain the cost of production of individual enterprises, and to determine the just profits of each enterprise from an estimate of the degree of skill shown in its design and management, then the just regulation of the prices of monopolized products would be utterly impracticable, because

nobody is competent to perform the operation. The inevitable result would then be the public ownership of all monopolized industries.

To come back to our special instance: The just difference in the price of the same quality of gas in two different cities is the difference in cost of production plus profit, in the two cities, if the gas were made and distributed in both cities by the most widely used method of production. The rate of profit to be allowed is the average rate in competitive industries at the same time and place. The cost of gas consists of cost of manufacture and cost of distribution. An experienced engineer, familiar with the costs and methods of laying gas pipes, must study the conditions affecting costs in the two cities, and must find the difference in costs of distributing gas, per 1 000 cu. ft. sold.

The quantity sold per mile of pipe has evidently an important influence on this cost of distribution. Municipal ordinances, the nature of the pavements, rates of wages, and costs of pipe, all influence these costs. An engineer who makes many such estimates will be able to develop rules by which it will be a comparatively simple matter to judge the quantitative influence of the various causes affecting the costs. In a similar manner, the cost of manufacture and the average leakage must be investigated by engineers familiar with the subject. The fact that only one, and this the best known, method of manufacture need be investigated, greatly simplifies matters. Since only differences in costs between different cities are needed, the influence of all the factors which are the same in the cities compared can be neglected.

In a similar manner, all other monopolies must be investigated. Just prices for monopolized products can thereby be established without interfering with the economy of production.

The process of obtaining just prices of monopolized products is evidently expensive and calls for commissions of experienced men of good judgment who have no other aim than justice.

Physical valuations of the property of monopolies, by determining the cost of reproduction less depreciation of their plants, are evidently of no use for this purpose. After just prices of monopolized products have been obtained, the just value of the securities of monopolies, or of the monopolies themselves, consists in the present value of their future dividends and interest payments. These can only be judged

with reasonable accuracy after the just prices have been in force for some years.

Before this, market values, where such exist, are the only guide. Where these are absent, the value of monopolized property is unknown and practically unknowable, unless the principles by which the future commissions will be governed are accurately known. In this latter case their course of action can be approximately foreseen, and the future prices and the consequent profits estimated; from these the just value of the properties can be judged with nearly the same accuracy as that of competitive enterprises.

With the proposed regulation of prices of monopolized products, the monopolists are left free to find and apply the methods of production which will obtain the desired products with the least effort. Those enterprises which succeed in reducing costs of production by introducing new and more efficient methods obtain all the savings secured in the form of increased profits, until the new methods become widely known and increase the average profit in the industry, when the regulation steps in and reduces prices. If fair competition had existed, the increased profits would have caused increased supply and consequent reduction of prices, to the same extent.

With the proposed method of regulation, the rate of profit in a monopolized enterprise is a true measure of the efficiency of management, while, without regulation, it may be only a measure of the degree of injustice of the prices exacted. With this regulation, the owners of the enterprises have in the rate of profit a measure of the capacity of their managers, and know when it is time to advance or discharge them. Such regulation, therefore, will increase the economy of production by enlarging the scope of able and removing incapable managers; it will thereby be for the ultimate benefit of both the owners and the customers of monopolies. The injustice of excessive profits or inferior efficiency of monopolized enterprises is more and more felt to be intolerable, and will inevitably lead, either to just control of prices, or to public management of all monopolies.

Government Monopolies.

Judged by an economic standard, the various governments—National, State, and Municipal—are a network of huge monopolies of which we are all compulsory owners and customers. The total

sum of the prices we all pay for their products is, as in private enterprises, equal to the total costs of production plus the total profits. The annual profits are equal to the increase in the value of the government property less the increase in the government debts. The net cost of the annual products is equal to the prices we pay less the annual profits. Since the profits, either positive or negative, belong to us, we are mainly interested in the cost of production, and not materially in the profits which come out of our pockets and afterward belong to us. In competitive industry and in private monopolies, justice to the consumer is obtained by either natural or artificial regulation of the prices of the products. In governmental activities, the net prices we pay necessarily equal the costs of production. Therefore, justice must be secured by regulating the cost of production. The only present attempt at such regulation is the periodical change of the managers. To secure real efficiency of production, we should have a reliable standard with which to measure the efficiency of our managers so that we may promote the capable and discharge the incapable ones. The best managers are those who secure for the desired quality of product the least cost of production. To obtain the best managers, and consequent economy of production, of all the services and products furnished us by governments, it is necessary, therefore, to ascertain, in every department of government action, the exact cost of production of all the products or services supplied. Only after, in every department of a large number of cities or States, the costs of production of every service or product have been ascertained and scientifically compared, by allowing for the quantitative effect of all those causes of difference of costs, with the most usual methods of production, which are independent of the skill of management, is it possible to judge reliably, and with the needed accuracy, the degree of economy of management of any department, or city, or State.

Thus far, the accounts of governments have not been kept in such manner as to enable one to ascertain correctly the cost of production per unit of any of the services rendered. The interest charges on all capital used, whether represented by debt or not, must, for rational comparisons, be included as part of the costs of production. Where comparison is desired with the prices of services rendered in other places by private monopolies, the taxes which a department would have to pay, if privately owned, must be included as part of the cost of

production. All the costs of production, per unit, for every government service or product, should be determined and all the quantities measured. The resultant total costs plus the profits should agree with the total payments by the consumers. The citizens, or owners, should be informed of the unit costs of all the products and services supplied.

As we need commissions to regulate justly the prices of the products of private monopolies, so do we need commissions to ascertain the just prices, or the costs with average efficiency of production, of the products and services of government monopolies. The just prices for any service or product of a government monopoly may be defined as those which, on an average, cover the cost of production, and which vary in time and place by amounts equal to the differences in cost of production resulting from causes independent of the skill of management.

No private business of large size with many departments could be carried on successfully without accurate cost-keeping in every department, and without changing the management where the resulting profits are unsatisfactory.

The scientific comparisons of the costs of production of the various government services and products cannot be made by individuals. A well-organized body of capable, experienced men is necessary, especially for ascertaining the quantitative effect of all those causes of differences of cost of production by the most common methods, which are independent of the efficiency of management and determine the just difference in costs or prices of different cities or States.

After this work has been accomplished, the reputation of public administrators will for the first time agree with the facts, and it will then be possible to treat justly our most important public servants. At present the relative merits of men, institutions and economic experiments can at most be judged qualitatively; a quantitative estimate and a quantitative social science will only become possible after the just and the actual prices of all the products and services furnished by governments are known. It must be conceded, however, that the difficulties of such comparisons are in some departments very great. Those departments where the quality of the services or products supplied can be measured most accurately, or where the products are uniform in different places, will, other things being equal, most naturally be taken up first, and after ample experience in these, others may be attacked.

The establishment and maintenance by commissions, of such prices, for the products of all private and government monopolies, as would prevail under free and fair competition, and the maintenance of such compensation, where it is practicable and economical, is a necessary part of the administration of justice, and is, therefore, pre-eminently a government function.

The regulation here advocated is just, is compatible with the highest efficiency of production, and greatly facilitates progress. With such regulation, Municipal, State, or National franchises need only prescribe the quality of service desired, stating that such prices will be allowed as will secure the same profits as would prevail under free and fair competition. The savings due to invention and progress of every kind with this regulation, after a short time, as in competitive industries, accrue to the public; and without injustice, the public can at any time change the quality of service demanded or the rate of taxation of the monopoly, because such changes will not affect its profits.

The objection will be raised that competition inevitably results in inadequate wages and lack of employment of the inefficient; that, therefore, to extend, in effect, the range of free competition to all the activities of man will lead to the permanent misery of a large class of the population; and that the proposed system of regulation is thereby condemned as unjust.

Justice consists in creating and maintaining such relations among men as will produce universal welfare. The existence of a large class of miserable people, therefore, is a sure indication of injustice. The regulation proposed would indeed be condemned if it implied the permanent existence of such a class. This class can only be helped by the will and the power of the more successful. The proposed regulation increases their wealth and the consequent power to assist those who cannot now be made efficient, and to provide the means for training the rest. The inefficiency is due partly to lack of proper training, partly to unsuitable ancestors. The only radical remedy, therefore, is an improvement in the methods of selecting the ancestors for the future generations and the training of their children. To achieve these results, increased wealth is most essential, and the best chance, even for the inefficient, lies in maintaining the most efficient system of production of wealth, which calls for industrial rewards in pro-

portion to efficiency, and in directing by public opinion and legislation the humane impulses of the wealthy toward the use of their power to the creation of universal industrial efficiency.

The proposed regulation of the prices of monopolized products and services requires the creation of State commissions in all the States, with power to enforce fair competition where practicable and useful, and to fix and maintain such prices for all monopolized products as will make the average profits of every monopolized industry, embracing many independent enterprises, the same as those of the competitive industries at the same time and place.

These, or separate commissions, should also ascertain the just prices for all products and services furnished by municipalities. These commissions must have power to prescribe and enforce for all municipalities such a system of cost-keeping as will determine correctly the unit cost of every product or service supplied.

National commissions with similar powers must be established to fix the prices for the monopolized industries engaged in interstate commerce and to ascertain the just prices for the services and products supplied by the States.

To ascertain the efficiency of the National governments, international commissions will be needed to find the just, and the actual, prices of all services and products furnished by them. Only in this way can the efficiency of all the departments of such governments be measured. The best managed departments and governments will thereby be pointed out; they can then be studied, and their best features adopted.

The difficulty of the work of these commissions increases with the size of the field of their activity and with large variations in the qualities of the services rendered, especially where quality is of supreme importance and where its value cannot be measured accurately. The regulation by State commissions of the prices of the products and services furnished by private monopolies and the fixing of the just prices for similar services and products furnished by municipalities is most easily accomplished. The fixing of the just prices for such immaterial services as public education is most difficult, but not impossible. It cannot be well denied that a well-argued valuation of the public education of all the States by the foremost educators of the country would give important clues leading to

the general improvement of public education. Such a valuation, however, would evidently be the most difficult work that could be given to a National commission.

It would not be hard to determine the degree of difficulty of the various kinds of work which must ultimately be done by such commissions. Other things being equal, the easier work should be undertaken first; but, as other things are not equal, the great importance of some of the proper work of such commissions requires it to be undertaken before much easier and simpler work is commenced. Where the absence of regulation does most harm, it must be undertaken, even where the difficulties are so great that complete success is impossible, since approximate justice is better than gross injustice.

The amount of human effort that is beyond the range of competition is constantly increasing the direct establishment and maintenance of just prices for all the products of private monopolies, and the indirect enforcing of such by ascertaining and publishing the actual and the just prices of all the services and products supplied by governments, is, therefore, an increasingly important part of the administration of justice.

The choice of the managers, of every grade, in all organized human effort, is the most influential factor in determining success or failure, increase or deterioration of efficiency, progress or retrogression.

For the best choice, a reliable standard of past, present, and future ability is a necessary condition. With the regulation proposed, private and public monopolies can, for the first time, at all times, measure the real ability of their managers by the profits in the first and by the costs of production as compared with the just prices in the latter. The best managed enterprises are thereby reliably pointed out, and their methods will spread rapidly. The ablest managers will rapidly obtain larger scope for their ability, and the incapable ones will be made harmless by discharge, in the same manner as in competitive enterprises. The just reproach of lack of economy and progress in monopolized enterprises will then to a large extent disappear.

The vast advantages secured by just control of the prices of monopolized products and services, therefore, fully justify the large amount of difficult work required from men of highest ability and the inevitably large expenses incurred to provide it.

Charging What the Traffic Will Bear.

There are still occasional advocates of the justice of the principle of charging what the traffic will bear; it is of importance, therefore, to ascertain the difference between the prices resulting from this principle and from the regulation here proposed. Assuming monopolists intelligently pursuing maximum profits and not fearing the loss of their monopolies, the resulting prices of their products may be calculated.

Let us assume that with p, the present price per unit of a monopolized product, the demand for it is q, the cost per unit, c; then the total profit is $(p - c)\ q$.

If the competitive or just price of this product is p, and if a reduction, dp, in the unit price increases the demand by dq, then it is profitable to make this reduction when the consequent increase of profit is larger than the competitive profit on the additional quantity produced.

The new profit is $(q + dq)\ (p - dp - c)$. The old profit was $q\ (p - c)$. The increase of profit, therefore, is

$$(q + dq)\ (p - dp - c) - q\ (p - c) = (p - c)\ dq - qdp.$$

The competitive profit on the additional quantity is $(p_1 - c)\ dq$. The price reduction, therefore, is profitable when $(p - c)\ dq - qdp > (p_1 - c)\ dq$, or when $(p - p_1)\ dq > qdp$, or when $p - p_1 > q\ \frac{dp}{dq}$.

$p - p_1$ is the difference between monopoly price and just or competitive price.

q is the quantity of demand, and $\frac{dp}{dq}$ is the ratio of reduction in unit price, to change in quantity of demand resulting therefrom. As long as this inequality exists, it is profitable to reduce the price. The price, therefore, will be reduced until $p - p_1 = q\ \frac{dp}{dq}$, or $p = p_1 + q\ \frac{dp}{dq}$.

The most profitable monopoly price, p, therefore, is larger than the competitive or just price by $q\ \frac{dp}{dq}$. This difference between

monopoly and competitive price is largest when a given change in price causes but small change in amount of demand, which is the case with very useful or necessary products.

It is smallest when a given change in price causes a large change in demand, which is the case with all luxuries which become accessible to larger numbers of consumers by a reduction in price.

The difference between monopoly and competitive price is also proportional to the demand; it is largest for articles of general consumption and small for luxuries.

It is evident, therefore, that uncontrolled monopolies are especially severe on the poor; and that monopoly prices are always higher than competitive prices.

When the monopolist fears the loss of his monopoly, he may reduce the price below the most profitable figure.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

RETRACEMENT-RESURVEYS—COURT DECISIONS AND FIELD PROCEDURE.

By N. B. Sweitzer, Assoc. M. Am. Soc. C. E.

To be Presented March 6th, 1912.

Volumes have been written on land surveying, from the simple schoolroom treatise to the numerous and extensive works on geodetic and topographic work, as well as on geodetic astronomy, which is associated therewith. Apparently, they all deal with one idea: the accurate measurement and calculation of lines and angles. This is necessary in such surveys as are required in the construction of a railroad or canal, the erection of buildings and bridges, and also the location of the geodetic co-ordinates for a point on the earth's surface from the heavenly bodies; but there are surveys differing from these, and, thus far, they have been neglected by the textbooks; and only the rapid settling of new countries, in recent years, by an advancing civilization, has demanded a fuller treatment of retracement-resurveys. This means that the theory of surveying in all its branches, as taught in our schools and colleges, should co-ordinate itself and recognize the fact that it has to deal with a new element, "The Error," and should treat it both in a scientific and legal way. The new engineer (and also the old one, for that matter) commences to dodge as soon as he finds himself coming in contact with this; it is his *bête noire.*

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Our early surveys are a mass of errors; and, in order to deal with them intelligently, the surveyor should have an exact knowledge of mathematics, a thorough understanding of the law applicable to boundary lines and old corners, and also a personal equation of adjustment for local conditions.

In the past, many rules have been made for special cases, for retracing old and erroneous surveys, only to be found wanting when applied in general. It is also true that what will hold good for small surveys, in field location, will not be practical when large areas are under consideration.

The present method of retracement-resurvey work, which has been carried on in Nebraska for the last few years, apparently solves the problem; and the following is a synopsis thereof:

Original Surveys.

The Act creating the present system of Government surveys of the public lands was passed in 1785; and, although differing in some respects from the present original surveys, the general scheme was practically the same in regard to the establishment of a rectangular system. This Act was followed by the organization of the personnel required to execute these surveys, and the appointment of a Surveyor-General, pursuant to an Act approved May 18th, 1796.

On April 25th, 1812, another Act was passed by Congress, providing

"That there shall be established in the Department of the Treasury an office to be denominated the General Land Office, the chief officer of which shall be called the Commissioner of the General Land Office, whose duty it shall be, under the direction of the head of the Department, to superintend, execute, and perform all such acts and things touching or respecting the public lands of the United States, and other lands patented or granted by the United States."

This was followed by several Acts to promote the well-being of the service when conditions required, among others, an Act, approved May 29th, 1830 (Secs. 2412 and 2413, R. S.),

"provides for the fine and imprisonment of any person obstructing the survey of the public lands, and for the protection of surveyors, in discharge of their official duties, by the United States Marshal, with sufficient force, whenever necessary."

Another Act, approved July 4th, 1836, reorganized the General Land Office and transferred it to the Department of the Interior.

The Act approved May 30th, 1862 (Sec. 2399, R. S.), reads:

"That the printed manual of instructions relating to the public surveys, prepared at the General Land Office, and bearing the date Feb. 22, 1855, the instructions of the Commissioner of the General Land Office, and the special instructions of the Surveyor-General, when not in conflict with said printed manual or the instructions of said Commissioner, shall be taken and deemed a part of every contract for surveying the public lands of the United States."

The last manual was issued under the above authority.

Reference to further Acts of Congress, defining the public lands survey, may be found in Volumes 1, 2, 3, 4, 12, 18, and 19, for the years 1796, 1800, 1805, 1820, 1832, and 1875, respectively.

It will thus be seen how, by Acts of Congress and instructions from the Commissioner of the General Land Office, the public lands were authorized to be surveyed.

It will be well to note the following Act, of February 11th, 1805, U. S. Statutes at Large, Vol. 2, p. 313, Sec. 2396, U. S. Revised Statutes:

"All corners marked in the surveys returned by the Surveyor-General shall be established as the proper corners of the sections or quarter-sections which they were intended to designate, and corners of half- and quarter-sections not marked shall be placed as nearly as possible equidistant from those two corners which stand on the same line.

"The boundary line actually run and marked shall be established as the proper boundary line of the sections or subdivisions, for which they were intended, and the length of such lines as returned by either of the surveyors aforesaid shall be held and considered as the true length thereof. Each section, or subdivision of section, the contents whereof shall have been returned by the Surveyor-General, shall be held and considered as containing the exact quantity expressed in such return; and the half-section and quarter-sections, the contents whereof shall not have been thus returned, shall be held and considered as containing the one-half or the one-fourth part, respectively, of the returned contents of the sections of which they may make part."

It will thus be seen that no dispute can arise in regard to the question of the permanency of the original surveys. Once made, and

legally accepted, they have to remain for all time the basis for all future deeds and conveyances, the statutes thus reiterating the common law. The original corners and lines, as shown by the monuments on the ground and the original maps and plats, stand as permanent and unchangeable monuments, and, together with the accompanying field notes and the original plats, form a basis, in the case of the disappearance of the original corners, by which they may be replaced by proportioning between original corners.

Section 99 of the Act of May 18th, 1796, and R. S. 2395, among other things, provides:

"The public lands shall be divided by north and south lines run according to the true meridian, and by others crossing them at right angles, so as to form townships six miles square; * * *

"Second. The corners of the townships must be marked with progressive numbers from the beginning; each distance of a mile between such corners must be also distinctly marked with marks different from those of the corners.

"Third. The township shall be subdivided into sections, containing, as nearly as may be, six hundred and forty acres each, by running through the same, each way, parallel lines at the end of every two miles; and by making a corner on each of such lines at the end of every mile. The sections shall be numbered, respectively, beginning with the number one in the northeast section, and proceeding west and east alternately through the township with progressive numbers till the thirty-six be completed."

Sec. 100, of the Act of February 11th, 1805 (R. S., 2396), among other things, provides:

"The boundaries and contents of the several sections, half-sections and quarter-sections of the public lands, shall be ascertained in conformity with the following principles:

* * * * * * *

"Third. Each section or subdivision of section, the contents whereof have been returned, by the surveyor-general, shall be held and considered as containing the exact quantity expressed in such return; and the half-sections and quarter-sections, the contents whereof shall not have been thus returned, shall be held and considered as containing the one-half or the one-fourth part, respectively, of the returned contents of the section of which they may make part."

From this it will be seen that no authority is given to make any more or less than thirty-six sections, containing, "as nearly as may

be, six hundred and forty acres each," to a township, or to make any other form of subdivision. However, this is qualified for a special case, by order of the President, as where land borders on rivers, lakes, and bayous. (R. S., 2396, Sec. 102.)

It is apparent that persons wishing to obtain Government lands file according to the original Government survey, as prescribed by the above law, the plats on file in the local land office and the boundaries of such lands as located by the original Government corners on the ground, and not according to a valley, stream, or other physical condition of the terrane. Now, until these laws are repealed, no more than thirty-six sections, consisting, "as nearly as may be" of "six hundred and forty acres each," can be numbered in a township; and any resurvey, in order to be legal, will have to relocate the original Government corners in their original positions.

Resurveys.

Justice Cooley, of the Supreme Court of Michigan, has written a most valuable article on "The Judicial Functions of Surveyors," which has been used by surveyors and engineers for years as one of their guides in retracing old lines. The general principles laid down are accepted without question as good law. However, Justice Cooley contemplated only the wooded districts of Michigan and adjoining States, where only comparatively small areas were in question, and where the footsteps of the original surveyor could be located positively, at no very great distance, by the remains of old bearing trees, permanent lakes, and well-cut banks of streams and rivers. He did not contemplate the great areas of land on the Western prairies, unmarked by a tree, uncut by lakes or streams—an undulating terrane where one square mile is a facsimile of the other, and where no natural object distinguishes one mile from another. The original field notes, for mile after mile, often read "40.00" and "80.00" chains, "over rolling sand hills." Nor did he contemplate the fact that vast areas in this region had never been surveyed on the ground, but had been platted and the plats placed on file, giving varying distances and areas to be filed on by settlers, and they would claim, on the ground, the distances and areas designated by the plats on file. Here, then, was a vast checker-board, as represented by the plats on file, with in-

numerable squares of varying areas, which should have corresponding areas on the ground. Obviously, if one of these checks were accidentally or wilfully misplaced, the whole scheme would be disturbed. A study of the situation will reveal the fact that to be harmonious with, and to fulfill the requirements of, the Court decisions, every claimant, where no original corners exist, is entitled to his lands as designated by the plat thereof, and, if the area on the ground covered by the platted areas contains more land than shown, he is entitled to his proportionate share. Otherwise, the harmony existing between plats and terrane will be disturbed, and some one not entitled to it will secure more than his just share. Likewise, a deficiency will cause an unjust loss of land.

Keeping the justice and equity of the foregoing always in mind, it is also well to remember that adverse possession does not run against the Government.

The following Court decisions in regard to resurveys are quoted from the works of F. Hodgman, Justice Cooley, and the late J. B. Johnson, M. Am. Soc. C. E.

"When boundaries mentioned are inconsistent with each other, those are used which best show the intention manifest on the face of the deed." (Gates *v.* Lewis, 7 Vt., 511.)

"Where one part of the description in a deed is false and impossible, but by rejecting that a perfect description remains, such false and impossible part should be rejected." (Anderson *v.* Baughman, 7 Mich., 79; Johnson *v.* Scott, 11 *id.,* 232.)

"Where boundaries of lands are fixed, known, and unquestionable monuments, though neither courses, distances, nor computed contents correspond, the monuments must govern." (Perman *v.* Wead, 6 Mass., 131; Nelson *v.* Hall, 1 McLean, U. S., 518.)

"Marked lines and corners control course and distance. Surplus lands do not vitiate a survey, nor does a deficiency of acres called for in a survey operate against it. Whenever the boundaries can be established, they must prevail." (Robinson *v.* Moore, 4 McLean, U. S. C. C., 279; Marrow *v.* Whitney, 5 Otto, U. S., 551.)

"A survey must be closed in some way or other. If this can only be done by following the course the proper distance, then it would seem that distance should prevail; but when the distance falls short of closing, and the course will do it, the reason for observing distance fails." (Doe *v.* King, 3 How., Miss., 125.)

"A line actually marked must be adhered to, though not a right line from corner to corner. When a line has been marked only part

of the way, the remainder of the line must run direct to the corner called for." (Cowan *v.* Perkins, 2 Jones Law Rep., N. Y., 222.)

"Of two overlapping surveys, the one first made has priority, particularly where the second is bounded with express reference to the first." (Van Amburgh *v.* Hitt, Mo. Sup. 22 S. N. W., 177.)

'The beginning corner of a survey, as given in the field notes, is of no more dignity than any other corner found on the ground." (Cox *v.* Finks, Tex. Civ. App., 41 S. W., 95.)

"Where original surveys *have been made,* and returned as a block into the land office, the location of each tract therein may be proved by proving the location of the block. Every mark on the ground tending to show the location of any tract in the block, is some evidence of the location of the whole block, and therefore of each tract." (Coal Co. *v.* Clement, 95 Pa. St., 126.)

"Where it is doubtful which of two lines of monuments is the true government line, other things being equal, that one is to be so taken which most nearly conforms to the field notes." (Hubbard *v.* Dussy, 22 Cal., p. 214.)

"Where a boundary line is assented to by the owner of a tract of land at the time when there was no dispute concerning such line, and on the supposition that it is the true boundary, he is not estopped, on discovering that such is not the case, from claiming title to the true boundary." (Schraeder Min. & Mfg. Co. *v.* Packer, 9 S. St., 385.)

"A county surveyor, employed to restore the lines and corners of adjoining tracts of land, according to the original government survey, found township corners only, then (the other quarter and section corners being missing), ran a straight line from one township corner to the other, and on this line placed the quarter and section corners, but did not take any testimony to ascertain the lines or corners of the original survey, did not attempt to prove his lines or corners by reestablishing the missing corners from all the known original corners, in all directions, did not sufficiently regard the field notes of the original survey, and did not, where the original monuments had disappeared, regard the boundary lines long recognized and acquiesced in. HELD: that such a survey is incomplete, and cannot be approved as the true and correct determination of the boundaries and corners, as originally established by the Government." (Reinert *v.* Brunt, 21 Kan., p. 807.)

"Lands sold under the U. S. surveys pass according to the description of the legal subdivisions, whether these subdivisions contain the legal quantity or not, more or less." (Fulton *v.* Doe, 6 Miss., 751.)

"Quarter posts of the Government survey are to be as much respected as the corners of townships or sections, however distant from the center line." (Comphall *v.* Clark, 8 Mo., 558.)

"If the distance between recognized Government corners, as originally established, over-runs or under-runs that given in the field notes, it should be divided *pro rata* between the intervening sections. The original field notes should be the main guide. Section corners being often deflected, the true corners must be tested by east and west distances from the recognized Government corners yet standing in the same township, as well as by north and south distances." (Martz *v.* Williams, 67 Ill., 306.)

"Unknown corners must be found by the corroborative testimony of all known corners with as little departure as may be from the system adopted on the original surveys, without giving preponderance to the testimony of any one monument above another.

"In re-establishing lost corners between remote corners of the same survey, when the whole length of the line is found to vary from the length called for, we are not permitted to presume that the variance arose from the defective survey of any part, but must consider, in the absence of circumstances showing the contrary, that it arose from the imperfect measurement of the whole line, and distribute such variance between the several subdivisions of the whole line in proportion to their respective lengths." (Moreland *v.* Clark, 8 Mo., 556.)

"The rule of common sense and of law is that the surplus or deficiency is to be apportioned between the lots, on the assumption that the error extends alike to all parts." (O'Brien *v.* McGrane, 29 His. Reports, 446; Quinnin *v.* Reizers, 46 Mich., 605.)

The early surveys of these Western plains were naturally hurried, from the nature of the case—contract work. The object of the surveyors was to run the greatest number of miles in the shortest space of time. Therefore, to them, time occupied in building corners was so much loss, and, as a consequence, the original corners were mostly of the minimum size, and sometimes of irregular shapes. Time and the elements soon apparently obliterated these corners. Whole townships and counties were thus affected, and, to make matters more complicated, when final occupation commenced, a vain search for corners was begun by, and unending lawsuits ensued among, the settlers and owners of these lands. In certain instances, some of the early contractors had neglected to set the interior section corners, and in other instances, even the town and range lines, or a check, were never surveyed, but, making bad conditions worse, false field notes were placed on file.

Here, indeed, was a complicated problem for adjustment. Note what the Courts say about resurveys, and how many questions of law and of a technical surveying nature are involved.

FIG. 1.—SURVEYING PARTIES, GARDEN COUNTY, NEBRASKA, MAY 1ST, 1911.

FIG. 2.—SURVEYORS' CAMP, GARDEN COUNTY, NEBRASKA, MAY 1ST, 1911.
2 FT. OF SNOW ON LEVEL.

FIG. 3.—OUTLINE OF EAST PIT OF ORIGINAL STANDARD
¼ CORNER, T. 25 N., R. 22 W., 6TH P. M., S. 36,
NEBRASKA, IN HEAVY SOIL. CORNER ABOUT 40
YEARS OLD; ALL SURFACE INDICATIONS
OBLITERATED.

A few years ago an attempt was made to ignore the early surveys, and other new surveys were made on top of the original ones, running straight lines without relation to the original corners. All went well for a few years, but the inevitable happened. For example: A filed on the original plat for Section 1; B filed on the new plat of an adjoining section. These did not agree, and, therefore, A and B went to the Courts. A township is like a checker-board—disturb one square and the others will have to be adjusted. The dispute of A and B disturbed the remainder of the township; and then came the search for original corners, as the Courts had always decreed. Land held, patented, and located on the ground, by the original corners, and taken in accordance with its accompanying map on file at the local land office, cannot easily be disturbed, when the claimant is aware of his rights, for our common law and the decisions above quoted, give him indisputable possession, for his patent is sacred; and such it should be; otherwise, no one would be secure in the possession of his holding, whether it were a dugout on a bleak prairie or the uncounted acres of some rich cattle baron.

Surveyors and others should remember the following, when attempting novel methods of surveying:

"All corners marked in the surveys returned by the Surveyor-General shall be established as the proper corners of the sections or quarter-sections, * * * and the length of such lines as returned * * * shall be held and considered as the true length thereof." (U. S. Revised Statutes.)

After reviewing the above, we are forced to recognize the following facts: Corners legally established by the Government remain fixed and cannot be changed, no matter how erroneous they may be. This, of course, refers to the Public Land Surveys, and affects land titles. The more we stop and consider how loosely these old surveys were made and how little attention was formerly given to them, either by those in power or by the people in general, the more we are surprised. Other great surveying departments of the Government, such as the Coast and Geodetic Survey, have always used the most refined methods, have had the best of personnel, and have taken ample time to measure and calculate lines and angles properly. Yet, when they find errors in their monuments or corners, no law intervenes to prevent them from correcting them and changing the corners. Corners of Public Land Surveys, however, cannot be changed,

and gross errors can never be eliminated. Now, under these conditions, it is not surprising that so little care was taken in the early public land surveys. Time and results have shown lack of care, and much of the blame should be laid on the contract system and rapid and cheap work. We certainly have had a sufficient amount of truly cheap original surveys, which, in the end, will entail far more expense than the original cost, in litigation and money, both to the Government and to the citizens affected thereby. In addition, they will check materially the development of the West, as permanent improvements cannot be placed on lands which are constantly threatened with lawsuits.

Original Monuments.

As this has to do with the prairie regions, a description of bearing trees is hardly necessary, but, in hunting for these accessories to original corners, it might be well to give a short explanation of how they appear years after they are marked.

After having established his corner, the Government surveyor oriented his instrument above it, and, selecting such trees as were required, took their bearing and distance. His assistants, in the meantime, made a cut about 4 in. wide and 30 in. long directly above the roots, with another blaze below this, 4 by 4 in. On the upper blaze was marked with a "scribe" the township, range and section; on the lower the mark, "B. T." Nature eventually healed this wound, and finally it barked over, no trace of the blaze remaining. However, the practiced eye can easily discern the indications of the axe mark in the bark above or below where the blaze commenced or ended. The new bark may be removed without defacing the old mark, by cutting, above and below where the old blaze started, to the depth of the old wound; then, with a boxing blow of the axe, the new growth will come off, leaving the letters, cut by the scribe years before, as plain as the day they were made. Furthermore, the piece which was removed will have the same letters in relief, and may be carried away and used as evidence, leaving Nature to repeat the same process of preserving the marks. The year in which the mark was made may be ascertained by the rings on the tree, and can be checked by the original record.

At first thought, one would suppose that the bearing tree was the only lasting natural accessory to perpetuate the original corner, and that the open prairies were deficient in that respect.

FIG. 1.—OUTLINE OF EAST PIT OF ORIGINAL SECTION CORNER, SECTIONS 35-36, S. C., T. 25 N., R. 16 W., 6TH P. M., NEBRASKA. IN SANDY SOIL AND HIGH GRASS. ORIGINAL CORNER TRAMPLED BY CATTLE. NO SURFACE INDICATIONS. AGE ABOUT 40 YEARS.

FIG. 2.—OUTLINE OF PIT OF ORIGINAL GOVERNMENT SURVEY, NEBRASKA, 40 YEARS OLD. NO SURFACE INDICATIONS, AND IN SANDY SOIL. MARKINGS ON BRASS CAP OF NEW IRON CORNER SHOWN IN UPPER LEFT CORNER.

Such, however, is not the case. The corners made in the original surveys on the open plains, where there were no rocks or stones, consisted usually of a mound of earth about 4 or 5 ft. in diameter at the base, 3 ft. high, with four pits, 18 by 18 by 12 in., north, south, east, and west, or northeast, southwest, etc., about 5 ft. from the mound.* The notes mention a deposit of charcoal, but, in practice this was very seldom made. Early surveyors like to tell the story that, as the regulations required the "deposit of a quart of charcoal," a quart of charcoal, well wrapped up in a canvas bag attached to a stout string, was actually deposited in the hole beneath the corner, with appropriate ceremonies, and immediately withdrawn, this same quart of charcoal doing duty for thousands of corners, in fact for a whole season's work. Stakes and posts were more often used. Their ends were frequently charred, and this was sometimes supposed to do duty for the charcoal.

Time has passed since these corners were originally made. The fierce winds of spring and fall, fanning the prairie fires, rapidly filled these pits with black ash and charcoal of burnt grasses and weeds, surface soils, and sands foreign in nature and color to their sides and bottoms, and soon leveled them, as well as the mounds of fresh earth. After the winter snows had gone and spring arrived, grasses and weeds quickly sprang up, sodding over both pits and mound, and obliterating, to all appearances, the boundaries of some one's home. These marks, however, were not really destroyed, for, with a light mould-board breaking plow, the sod may be turned back, and, as it curls up, a discoloration different from the prevailing color of the sod appears. Then, with spades sharpened to a beveled edge by files carried for that purpose, these discolorations may be "shaved" and the outlines of an original pit soon appear, the charred grasses and foreign soils and sands, which filled it, showing plainly in texture and color against the homogeneous soil of its sides. The remaining pits may soon be disclosed, and the original corner re-established and perpetuated by the cement and brass-capped monument now used by the Land Office.

Thus, after all, the method of finding the original marks on the

*In regard to the direction of the pits, in the original corners, from the mound, no set rule seems to have been followed in the early surveys. In the same contract and township, pits were placed sometimes north and south of the mound, and sometimes east and west. Their sizes also vary.

bearing tree in the forest is practically the same as locating the corresponding corner on the treeless plains of the West.

Having reviewed some of the Court decisions affecting resurveys and indicated the method of searching for an original corner in the forest and on the plains, the methods of field procedure will be described.

A Township Originally Partly Surveyed.

It will be assumed, first, that a township has only been partly surveyed by the deputy surveyor, or that only a portion of his original corners can be found.

First, make a resurvey of the exteriors; find all original corners possible, and proportion in those corners where the original ones cannot be found. Make a closed survey; then find the length and bearing of a line starting from the center of the south town line, or corner to Sections 33 and 34, which will intersect the corner on the north town line, or the corner to Sections 3 and 4, or conversely, or the line nearly at right angles about 6 miles long east and west through the township. The former is preferable as convergency does not enter into the field work. Run this line, searching for original corners, and placing temporary mile and half-mile points, locating all original corners by rectangular co-ordinates to this line. When the original corners are found, tie them to each other and the exteriors by true course and distance, calculated by this line; continue this process through the township north and south, east and west, until all original corners are found. It will be apparent, from the foregoing method, that the original surveyor, starting from any corner on one side of a township, no matter how he wandered in setting his corners in the central part of the township, must ultimately arrive at the corner on the opposite side. Therefore, having the calculated course and distance, one has a definite line to run, and must sometime cross his course, or at least arrive at the same corner, and thus have a better chance to find his marks, than any haphazard interior line which may be guessed at as a random.

Now, assume that the southwest nine sections have not been surveyed, or that the original corners cannot be found. One has the 3 miles of township exterior from the southwest corner of the township north and the 3 miles east, and the course and distance between the interior section corners, north and south, east and west, opposite

these lines. Make a complete closure of this area; calculate the distances from the interior section corners to their opposite corners, in this area, on the town and range lines. After these distances have been secured, taking the original plat, proportion in the 3 miles north, south, east, and west. Now, having the courses and distances of the perimeter of this area, and the proportional distances of every mile of its interior, the courses and distances of all interior miles can be calculated. This will furnish all necessary data to locate on the ground all missing corners in this portion of the township.

A Township Never Originally Surveyed.

As in the foregoing illustration, find all original corners on the exterior of the township and relocate all missing exterior corners by proportional measurements from the original plat; then proceed to search for original corners on the interior, as explained in the previous case. Having ascertained that none exist, or that the township was never originally surveyed, proceed as follows: Calculate the distances through the township on section lines north, south, east, and west. Then, taking the original map as a basis, give each mile in the township its proper proportional distance. (Always check a given north area against a south area, an east area against a west area. They will always check if the exteriors are an accurate closure.) Now, having all interior lines properly proportioned, the courses are thus secured: Take the center line north and south, the line between Sections 33 and 34; take the sum of the south boundaries of Sections 34, 35, and 36, the course of the east boundary of Section 36 (algebraically), and the sum of the north boundaries of the above sections; then the difference of the easting and westing, not neglecting curvature, will give the course sought. Then, check to the west the north and south boundaries of Sections 33, 32, and 31, with the course of the west boundary of Section 31, which should give the same result as that secured above. The remaining 5 miles north to the corner of Sections 3 and 4 may be secured in the same way, checking east against west, the courses of all north and south lines being secured in the same manner. The east and west miles are secured by the same method. The course of the line between Sections 13 and 24 is the difference of the east and west boundaries of Sections 1, 12, and 13; get the course of the north boundary of Section 1; then the difference

of northing and southing will give the course of the line between Sections 13 and 24. Check by the difference of northing and southing of Sections 24, 25, and 36, and the south boundary of Section 36. The lines between Sections 14 and 23, 15 and 22, 16 and 21, 17 and 20, 18 and 19 are secured in the same manner, as are the remaining east and west miles.

Having, then, the data to place it instrumentally on the ground, commence, if possible, at the corner to Sections 33 and 34 on the township line. Run the calculated courses and distances as a random line to the corner of Sections 3 and 4, on the opposite town line, setting temporary corners at the calculated corner and quarter-corner positions, and correct back on the true line. Then start, if possible, at the corner to Sections 13 and 24 on the east range line, and run the calculated courses and distances as a random line to the corner to Sections 18 and 19 on the west range line, setting temporary points as above, and correcting back. This will locate the center of the township, and the remaining quarters can be located as above.

Now, this fulfills the requirements of the Court decisions, giving all claimants their proportional part of all excesses, and also divides proportionally all deficiencies, as by this method no excesses are carried into any part of the township.

Checks between standards and parallels affecting the town and range lines are effected in the same manner. Always work from the center toward the exteriors, having first made a closed survey of the exteriors. The method of differences will shorten the proportional method when the differences are not too great.

Instruments.

The original surveys were made, as a rule, with the solar. This instrument, in the hands of a competent instrument man, gives good results, especially in timber and brush, where many sights are taken in a mile. When in adjustment, it also gives a good approximate meridian, and, as used by the average transitman, in a hurried set up, when many sights are used, the error, if any, tends to counterbalance. In an open country, however, the tendency is to take a few hurried solar observations, where long sights can be easily secured, and then resume the tangent lines. This gives a ragged line; and long experience has shown that, while sometimes good closures result,

many of the courses which cause trouble with interior section closures are not correct, but tend to balance in the final result. This being the case, only transit lines should be used; and a light mountain transit is advised. Observations on Polaris or any circumpolar star are most readily made, and an elongation observation or an approved daylight hour angle or two should be taken on every township exterior, and one for the interiors. All lines should be back and fore transit lines, double-centered, when necessary.

The chains should be tested every two or three days, and, if a tape is used, care should be taken to see that the handles are not sprung.

Transits should always be in adjustment, as the time required to keep them so is only a few minutes, and is much less than necessary with a solar instrument.

Observations.

The following observations should be used on circumpolar stars, and on equatorial stars only when the situation demands.

The elongation observation will not be given in detail, as the procedure is so simple that it seems unnecessary. It might be pertinent, however, to state that the instrument should be in perfect adjustment, especially the levels. Always take direct and reverse pointings at the star. Place the mark on the sky line, about 30 chains distant, so that, if possible, it is east of the star for east elongation and west of the star for west elongation. Use an electric flash-light for the cross-hairs and to read the verniers. Read both verniers. The surveyor should not wear a long coat which the wind will blow against the tripod legs while he is taking an observation.

To compute the azimuth of a circumpolar star at elongation, use the equation:

$$\sin. A = \sec. \phi \cos. d.$$

To know the time of elongation, use the following:

$$\cos. te = \tan. \phi \cot. d.$$

The hour angle, added to the right ascension, equals the sidereal time of the star's elongation; reducing to mean time, equals the local mean time sought.

The "American Ephemeris" should be consulted for right ascension and declination.*

* See "Fixed Stars, Constants of Struve and Peters." For elaborate methods of azimuth at elongation, see "Geodetic Astronomy" (John F. Hayford, M. Am. Soc. C. E.,) George C. Comstock, W. W. Campbell, and others.

The most convenient form of observation, and the one that will appeal to the engineer most, on account of its convenience, is that by the daylight hour angle.

After running on a tangent all day, the writer, just before sundown, as the wagons were swinging into camp, has often set up in front of the place where his tent was to be pitched, and, using a mark on the sky line perhaps a mile away, observed Polaris, securing at least two direct and two reversed observations. The whole series usually does not take more than 15 min., the sun being still many minutes from the horizon. This is entirely a daylight operation, no lamps being required to illuminate the cross-hairs and verniers, hence there is little chance of error from this source.

The operation is very simple. Having the tangent, as assumed above, the north point is easily approximated. The position of Polaris for that date is calculated roughly (either for upper culmination or elongation), and its position relative to the celestial pole is found. Then, orienting the instrument on the meridian, fix the telescope on sidereal focus, point the line of collimation to the celestial pole by means of the vertical arc, then raise or lower it according as the star is above or below the elongation points, and move it east or west according as the star is east or west of the celestial pole: If it is required to be exact, use the following:

$$\text{Tan. } A = \frac{\text{sin. } t}{\text{cos. } \phi \text{ tan. } d - \text{sin. } \phi \text{ cos. } t}$$

which is the azimuth of Polaris at any hour angle. In this and for nearly all observations, every practicing engineer and surveyor should have the pamphlet of the General Land Office on the azimuths of Polaris, in which this is all tabulated. It takes but a moment to secure the necessary functions of the star and the azimuth required for the line check. One should not be discouraged if the star is not found at once. When the eye does discover it, it looks like an electric bulb.

Taking advantage of a clear evening, on May 1st, 1907, the writer secured the correct time by telephone from the Western Union telegraph office, and found that his watch (Waltham Vanguard, No. 11 000 844) was 2 min. slow. Then the following daylight observations were made on *Alpha Ursæ Minoris*. No lights were required, as the cross-hairs and verniers were plainly visible. A mark was set on the

sky-line 30 chains north, and slightly east, as shown by the subsequent observation. The levels were in perfect adjustment, the bubbles remaining in the center of the tubes continually.

May 1, 1907; Lat. 42° 33′ N.; Long. 101° W. Gr.

Watch slow 2 min. of Standard time, 105° Mer.

Angle, Azimuth mark to star,

	Time.		*Direct.*	
	h. m.	A	B	Angle.
	6 55	9° 56′	189° 56′	9° 56′
	7 00	9° 55′	189° 55′	9° 55′
			Reversed.	
	7 10	9° 53′	189° 53′	9° 53′
	7 13	9° 53′	189° 53′	9° 53′
Mean =	7 04.5			9° 54.5′
Watch correction...............	2.0			
Correct astron. time, 105° Mer..	7 06.5			
Reduced to 101° Mer...........	16.0			
Local mean time (astron.)......	7 22.5			
	24 00	h. m.		
Time of obs., Apl. 30, 1907.....	31 22.5	31 22.5		
		22 51.5		
Hour angle =		8 31.0		
U. C. Polaris, May 1, 1907...................		22 47.6		
		3.9		
U. C. Polaris, Apl. 30, 1907....		22 51.5		

Azimuth, Polaris at obs. = 1° 15′ E.

9° 54.5′
1° 15.0′

8° 39.5′ = Meridian W. of mark.

A. M. and P. M. equal altitude observations of the sun, check the meridian. Frequently circumpolar stars cannot be caught on account of local conditions. Then one has to observe equatorial stars; and, in some cases, as the sun, the following is an example:

During the execution of Government surveys in the Olympic Mountains in 1898, for many weeks at a time, circumpolar stars were invisible, on account of the Sound and Pacific fogs, the deep, narrow cañons, and the immense trees. The only heavenly body obtainable for azimuth in that region, with any constancy, therefore, is the sun.

and its apparently somewhat erratic path through the heavens, as compared with the fixed celestial bodies, was more difficult to calculate than that of a star. The writer devised the following method of equal altitudes of the sun for azimuth, and this has since been adopted by the U. S. Government for like conditions. It is entirely novel, nothing like it appearing in any textbook on engineering. The following is an example:

On May 2d, 1907, at 8.30 A. M., the writer observed the sun with a Young and Sons light mountain transit, No. 7 598, with solar attachment, setting off 15° 10′ 30″ on the declination arc, and 42° 33′ on the latitude arc, thus securing a solar meridian, which was checked as follows, for a true meridian, by equal altitudes of the sun for the two astronomical triangles, A. M. and P. M.: the azimuth mark 30.00 chains north, as given by the solar observation; altitude and azimuth of the sun corrected for refraction and semidiameter; angles taken to the nearest minute; standard time, 105th Meridian.

Lat. ϕ 42° 33′. Long. λ 101° W. Gr. Decl. δ 9 A. M. 15° 10′.

$$\text{Tan.}^2 \tfrac{1}{2} A = \frac{\sin. (S - \text{Co-Alt.}) \ \sin. (S - \text{Co-Lat.})}{\sin. S \ \sin. (S - \text{Co-Decl.})}$$

A. M. triangle.

Alt. = 42° 49′

t = 90° 00′

Co-Lat.	47° 27′	84° 44′	84° 44′	84° 44′
Co-Alt.	47° 11′	47° 11′	74° 50′	47° 27′
Co-Decl.	74° 50′	37° 33′	9° 54′	37° 17′
2)	168° 88′			
	84° 44′ = S			

Log. sin. 37° 33′ =	9.784941	
" " 37° 17′ =	9.782298	
	19.567239	19.567239
Log. sin. 84° 44′ =	9.998163	
" " 9° 54′ =	9.235349	
	19.233512	19.233512
Log. Tan.^{2} $\frac{1}{2}A$		2)0.333727
" " $\frac{1}{2}A$		0.166863
$\frac{1}{2}A$ =		55° 44′ 45″
A =		111° 29′ 30″

$$\left.\begin{array}{l}\text{Alt.} = 42^\circ\ 49' \\ t = 90^\circ\ 00' \\ \text{Decl.} = 15^\circ\ 14'\end{array}\right\}\text{P. M. triangle.}$$

Co-Lat. 47° 27′	84° 42′	84° 42′	84° 42′
Co-Alt. 47° 11′	47° 27′	74° 46′	47° 11′
Co-Decl. 74° 46′	37° 15′	9° 56′	37° 31′
2) 168° 84′			
84° 42′ = S			

Log. sin. 37° 31′ =	9.784612	
" " 37° 15′ =	9.781966	
	19.566578	19.566578
Log. sin. 84° 42′ =	9.998139	
" " 9° 56′ =	9.236795	
	19.234934	19.234934
Log. tan.^{2} $\frac{1}{2}A$		2)0.331644
" " $\frac{1}{2}A$		0.165822
$\frac{1}{2}A$		55° 40′ 55″
A		111° 21′ 50″
		111° 21.83′

The A. M. triangle gives an azimuth of	111° 29.5′
The P. M. " " " " "	111° 21.83′
2 dA =	7.67′
Azimuth of astronomical triangles, taken from N. dA =	3.83

As a check on the foregoing equal altitude observations, the writer uses the following :

$$dA = \frac{\frac{1}{2}\,(\delta - \delta)}{\cos.\ \phi\ \sin.\ \frac{1}{2}\,(t + t)}\ .$$

$\frac{1}{2}\,(\delta - \delta)$ = Log.	0.301030
Cos. ϕ 42° 33′ "	9.867283
sin. $\frac{1}{2}(t + t)$ 45° "	9.849485
	19.716768
	0.584262

dA = nat. 3.83′ ; dA to be turned from bisection of angle (360° — 222° 51.33′) from South to East.

Standard Parallels.

After the observations for meridian, the most important thing is to project the line thus secured. The meridian projected north and south, of course, needs no introduction; but a projection of the meridian as a true east and west line does. Books on surveying contain many tables and interesting and complicated formulas in reference to the methods of projecting a parallel of latitude with a transit instrument. Most of them make interesting mathematical problems for the office, but, for the locating engineer and his assistants, the interest ceases when field work commences.

The tangent and secant methods are the ones most used. The trouble with the tangent method is that it departs from the parallel as the square of the distance increases and soon the transit line is so far from the objective that the topography materially differs, and in timber country the cutting is not on the true line. The secant method is complicated. It first starts south of the parallel, then is north of it, and, then, again is south, in 6 miles. This means that the offsets are first made north, then south, and then again north. As most of these offsets are made by assistants, this method requires a higher standard of efficiency than is generally met by the average flagman and chainman, and is conducive to error.

To avoid the deficiencies of these methods, the writer has been using the following for some years past, and finds it practical. An example will illustrate:

At the corner to Sections 31 and 36, on the 4th Standard Parallel North, 6th P. M., Nebraska, between Ranges 32 and 33, West, after observing *α Ursæ Minoris* in the usual manner, the line was run east on the 4th Standard Parallel 40 chains, 0 links north to parallel; 1 mile, 1 link north to parallel; 1½ miles, 2 links north to parallel; 2 miles, 3 links north to parallel; 2½ miles, 5 links north to parallel; 3 miles, 8 links north to parallel. At this point the writer turned a deflection angle of 4½′ north, and proceeded as above, and at the 3-mile point arrived at the corner 6 miles east of where he started, and his course there was due east.

In this method the assistants have only to remember 3 miles of offsets, as the last 3 miles in a township are the same as the first and decreasing; and, if the offsets are forgotten, they are easily

calculated by remembering that they vary as the square of the distances in miles.

Table 1 gives the offsets, in links, from the tangent to the parallel:

TABLE 1.—TRAVERSE-TANGENT: OFFSETS, IN LINKS, FROM TANGENT TO PARALLEL.

Latitude.	Miles.						Deflection angle.	Tangential angle.
	½	1	1½	2	2½	3		
35°	0	1	2	3	4	6	3′ 38″	1′ 49″
36°	0	1	2	3	5	7	3′ 46″	1′ 53″
37°	0	1	2	3	5	7	3′ 55″	1′ 57″
38°	0	1	2	3	5	7	4′ 04″	2′ 02″
39°	0	1	2	3	5	7	4′ 13″	2′ 06″
40°	0	1	2	3	5	8	4′ 22″	2′ 11″
41°	0	1	2	4	5	8	4′ 31″	2′ 15″
42°	0	1	2	4	6	8	4′ 41″	2′ 20″
43°	0	1	2	4	6	8	4′ 51″	2′ 25″
44°	0	1	2	4	6	9	5′ 01″	2′ 30″
45°	0	1	2	4	6	9	5′ 12″	2′ 36″
46°	0	1	2	4	7	9	5′ 23″	2′ 41″
47°	0	1	2	4	7	10	5′ 34″	2′ 47″
48°	0	1	3	4	7	10	5′ 46″	2′ 53″
49°	0	1	3	5	7	10	5′ 59″	2′ 59″
	5½	5	4½	4	3½	3		

This table can be used for any angle from the east and west cardinals by multiplying the deflection angle and corresponding offsets by the cosine of that angle.

To prevent a repetition of past errors in measurements and alignment, modern methods are replacing the crude devices of the past, and better instruments are taking the place of those formerly used. One of the greatest advances has been made in corner material. The old corner used throughout the plains country of the West, was a makeshift, which is now replaced by one that is practically indestructible, of cast iron, cement, and brass, with the township, range, and sections plainly indicated.

It is of more material benefit that men of a different class are giving their attention to surveying in all its branches. The old-time local practitioners are giving way to men who have more education, and the attention of the Engineering Profession is being called to a vocation once much neglected.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONSTRUCTION OF THE MORENA ROCK FILL DAM, SAN DIEGO COUNTY, CALIFORNIA.

Discussion.*

By Messrs. George L. Dillman, George F. Maddock, J. D. Galloway, H. Hawgood, and F. B. Maltby.

George L. Dillman, M. Am. Soc. C. E. (by letter).—As Mr. O'Shaughnessy has given the writer some credit in the paper, it may not be amiss to enlarge on the great "Hydraulic Principle." This principle applies to practically all hydraulic construction. It has been persistently ignored by many alleged experts, always to the detriment, and often to the destruction, of the works. Where intelligently applied, the result has been safety and economy. Just why it has not been announced by the great writers on hydraulics and taught as a fundamental principle in engineering schools has never been apparent to the writer. Mr. Dillman.

Briefly stated, the principle is this: Construct one impervious surface, and build the rest of the structure to support that surface. If this surface should not be water-tight, make it as nearly so as possible, in order that seepage or leakage will not be allowed to accumulate pressure against some other surface, or do other damage in getting away.

In the case of masonry or concrete dams, the particular part to make tight is the up-stream face. If this is tight and supported, the result will be a dam; otherwise, a failure. This support is: (1) Solid masonry or concrete, the result being the so-called uniform-sectioned type; or, (2) Buttresses of masonry or concrete, resulting in

* This discussion (of the paper by M. M. O'Shaughnessy, M. Am. Soc. C. E., published in *Proceedings* for October, 1911, and presented at the meeting of December 20th, 1911), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Dillman. the multiple-arch dam—safer and more economical; or (3) A mass of loose rock, as in the present case, resulting in a stable structure.

In (1), special care must be taken that the up-stream face is the least pervious surface, because, making any other surface tighter would tend toward weakness. Carried to the limit, making the down-stream surface of ordinary types the most nearly water-tight would insure failure. In (2), the multiple-arch or buttressed-wall type, no special care need be taken. Seepage will find its way out through the arches. In (3), or the present case, the loose rock fill takes care of the seepage if only ordinary care is taken in clearing the foundation for it.

The particular method of supporting the impervious (or most nearly impervious) surface is generally a matter of dollars and cents. That the author has chosen the best one must be conceded, when the price of cement is considered. In other words, the loose rock wall undoubtedly costs less than any other support. To have placed any fine material in the loose rock would have been a mistake, not necessarily fatal, but an added expense, possibly resulting in failure. It costs money, does no good, and may be harmful; yet it has been done recently in California.

In the case of earth dams, with special cores of puddled clay, masonry, or steel, earth on the up-stream face acts in one of two ways. It may be impervious, making the core unnecessary, or it may be merely a support to the impervious core. This earth generally needs rip-rapping or paving, in order to resist wave action. In the case of puddle, it is necessary to prevent the puddle from drying out. In the case of masonry or steel, it seems to be unnecessary, as masonry or concrete could be built on a batter which would obviate the need for support. As steel is not a permanent construction material, its life would depend on its coating, which itself might require some protection; but the down-stream material should be pervious. All possible seepage through the core should get away without eroding the material or producing pressure.

In the case of timber dams, the structure that stands is a face of planking connected with sheet-piling, as tight as the builder can make, supported by cribs, bents, loose rock, or something else, but always following the "Hydraulic Principle." Tightening it in more than one place is expensive and often fatal.

Other structures may well be mentioned here. A retaining wall should always have drains through it to prevent it from becoming a hydraulic structure. A steel tank or steel pipe should always be caulked on the inside, as the outside caulking only forms a small lip for tightness and soon rusts off or is forced open, whereas the inside caulking has the necessary support. In a reinforced concrete reservoir, the concrete forms the impervious surface, the steel its support. The

location of the reinforcement and its initial tension, are matters of moment. If the reinforcement is put in without initial tension, the concrete must give before the strength of the reinforcement is developed—this is the most common cause of leaky structures. Other cases of application cannot fail to occur to readers. The application of the principle cannot help but be efficient and economical. Mr. Dillman.

This may not be a discussion of the paper in the sense usually intended. The author seems to have covered the subject completely. California has a great number of dams, and many extremes of types, and this seems to add another, for the writer knows of no rock fill dam of greater height. San Diego is to be congratulated on the assurance of a continued and increased water supply, Mr. O'Shaughnessy on having constructed a great dam, and the Society on having such a complete description of it.

George F. Maddock, Esq. (by letter).—In connection with the data in this paper, it may be of interest, to those who have to do with hydraulic development in semi-arid countries, to present a brief synopsis of a report made by Mr. O'Shaughnessy for the writer, on the run-off from 210 sq. miles of the water-shed of the San Luis Rey River, in the eastern part of San Diego County, California. In order to study these conditions, isohyetose lines, or lines of equal rainfall, were drawn on the United States topographical map of Southern California. The data for locating these lines were secured from the United States Weather Reports and from private records. The rainfall stations covered a wide area, and varied in elevation from sea level to 5 300 ft. As will be seen from Table 5, the observations covered Mr. Maddock.

TABLE 5.—Rainfall Stations, San Diego County, California, and Vicinity.

Name of station.	Elevation above sea, in feet.	Length of observation period, in years.	Average annual rainfall, in inches.
Elsinore	1 234	12	13.64
Fall Brook	700	27	17.14
Valley Center	1 365	26	20.03
Escondido	657	14	15.15
Poway	460	29	13.79
El Cajon	482	10	12.24
San Diego	Sea	53	9.62
Sweetwater Dam	238	20	9.52
Jamul	900	6	13.00
Barrett Dam	1 600	5	19.07
Campo	2 189	31	19.98
Morena Dam	3 300	5	24.15
Buckman Springs	3 500	2	19.90
Noble's Mine	4 200	3	24.5
Cuyamaca Reservoir	4 677	21	38.84
Julian	4 250	28	26.36
Santa Ysabel	2 983	10	24.17
Mesa Grande	3 300	5	30.70
Nellie	5 300	7	44.26
Warner's Springs	3 165	4	16.08
Salton Sea	Sea	30	3

Mr. Maddock. many years. These isohyetose lines divided the water-shed into precipitation zones, and the rainfall on each zone was estimated by assuming the average between each boundary. The run-off was computed from percentages obtained from the Cottonwood observations.

Tables 5, 6, and 7 give the precipitation records, the run-off observations on the Cottonwood water-shed, and the estimated run-off for the 210 sq. miles of the San Luis Rey water-shed (Warner's Ranch).

TABLE 6.—RUN-OFF FROM COTTONWOOD WATER-SHED ABOVE BARRETT.
Area, 250 sq. miles.
Elevation, 1 506 to 6 000 ft.

Year.	Mean rainfall, in inches.	Run off, in inches.	Run-off, in acre-feet.	Percentage of run-off to rainfall.
1906	32.33	3.7	59 870	11.5%
1907	15.68	2.12	34 000	13.4%
1908	18.69	0.81	12 970	4.3%
1909	28.76	1.82	29 190	6.3%
1910	12.61	1.05	16 870	8.3%
Total for 5 years	....	....	152 900	43.8%
Mean	....	....	30 580	8.76%

TABLE 7.—ANNUAL RUN-OFF FROM WARNER'S WATER-SHED.

Rainfall.	Area.		Average depth of rainfall, in inches.	Percentage of run-off.	Run-off, in inches.	Seasonal run-off, in acre-feet.
	Acres.	Square miles.				
Between 45 and 40 in.	6 080	9.5	42.5	18.8	8	4 054
" 40 " 30 "	9 216	14.4	35	12.8	4.5	3 456
" 30 " 25 "	11 520	18	27.5	8.0	2.2	2 112
" 25 " 20 "	16 128	25.2	22.5	7.5	1.7	2 293
" 20 " 15 "	55 680	87	17.5	7.0	1.2	5 568
" 15 " 10 "	35 776	55.9	12.5	6.5	0.81	2 415
Totals	....	210.0	....	....	....	19 848

The foregoing analysis of this water-shed, when proper storage was considered, indicated that only 20 cu. ft. per sec. were available for power during the long periods of drought which occur in this locality. This is slightly less than 0.1 cu. ft. per sec. per sq. mile of water-shed, and agrees remarkably well with the Government observations of this stream at Pala.

Mr. Galloway. J. D. GALLOWAY, M. AM. SOC. C. E. (by letter).—This dam is a notable addition to those of the type which have been built in Western America, and is a credit to Mr. O'Shaughnessy, the designer and builder.

Mr. Galloway.

The Morena Dam differs in one respect from other rock fill dams in the method of constructing the face or water-tight skin. Mr. O'Shaughnessy has made the face of large stones set in cement mortar, and from his description it would seem that it is the intention to allow water pressure against this face before the concrete slabs, 1 ft. thick, are added. It would be interesting to know the head of water to which the rubble masonry was subjected before the concrete slabs were placed, and if any increase in leakage resulted.

The problem of the water-tight skin is the most serious one to solve in dams of this type. A timber skin, consisting of three layers of planking, has been used on a number of dams. This is an expedient only adopted to save money. It is possible to make a water-tight skin in this way, and this was used by the writer in the design of two rock fill dams noted below. The placing of a diaphragm in the center, as in the Lower Otay Dam, is not believed to be good practice. The water-tight skin should be placed on the water face of the dam.

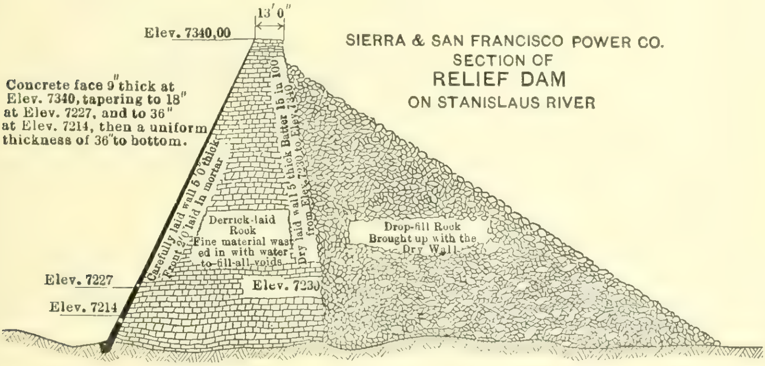


Fig. 6.

The use of reinforced concrete, as far as the writer knows, was first tried on an extensive scale at the Relief Dam, of the Sierra and San Francisco Power Company, in California. This dam was built in 1908 and 1909 under the supervision of Messrs. Sanderson and Porter, Constructing Engineers, of New York, with Messrs. C. D. Marx, Wynn Meredith, Donald Frye, and the writer as Advisory Engineers. The dam is 140 ft. high; Fig. 6 is a cross-section. In the opinion of Professor Marx and the writer, it was necessary to have a diaphragm of sheet steel embedded in concrete for the face. The other engineers believed that the concrete would withstand the pressure of water, and experience has proved the correctness of this idea, as the dam was built with a reinforced concrete skin 3 ft. thick at the bottom and tapering to 9 in. at the top.

Mr. Galloway.

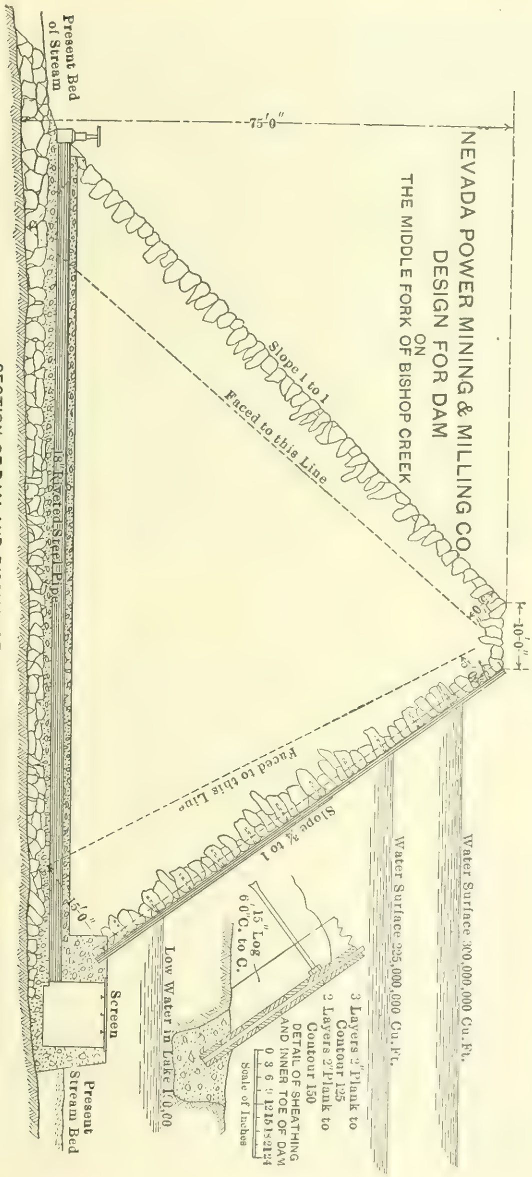
Another point to which attention should be called is the necessity of having a substantial backing of derrick- and hand-laid rock behind the water-tight skin. In the Morena Dam this backing is 50 ft. thick at the bottom. In the Relief Dam the backing is 100 ft. thick at the bottom and 13 ft. thick at the top. The face behind the concrete is laid in cement mortar for a thickness of 2 ft.

The writer takes this occasion to call attention to what is likely to happen to an engineer when he does not superintend the building of a structure for which he has made the design. In December, 1905, the writer prepared plans of two rock fill dams for the Nevada-California Power Company, on Bishop Creek, California. The dams are at an elevation of about 8 500 ft., and are in a very remote part of the State. For reasons of economy, timber faces were designed. Each dam was about 75 ft. high, and the design followed closely that of the Bear River and Meadow Lake Dams of the Standard Electric Power Company, now a part of the Pacific Gas and Electric Company. These dams on the Mokelume River, also about 75 ft. high, were built by W. R. Eckart, M. Am. Soc. C. E., about 1899 and 1900. Fig. 7 is a cross-section of the dam on the Middle Fork of Bishop Creek as designed. The water face has a timber skin of three layers of plank. The design called for a backing of derrick-laid rock, as shown, on both the front and back of the dam.

In the strenuous times following the earthquake of 1906 in California, the writer severed his connection with the Power Company, and the construction of the dam on the Middle Fork, which had just started, was carried out by others. The derrick-laid rock was omitted on the Middle Fork Dam, with the result that settlement took place, distorting the timber face and causing considerable leakage. The settlement was as much as 3 ft. in some cases. Plate IX shows the distorted sheathing.

In the description of the Morena Dam, Mr. O'Shaughnessy notes the necessity of having the quarry waste segregated from the loose rock fill at the back of the dam. A difference of opinion might exist on this point. The writer believes that if the fill be made of all sizes of rock, from quarry waste up, there will result a more compact mass, which is less likely to be distorted than if only large stones are used. The analogy is suggested by the compactness of a well-laid macadam pavement which resists distortion under exterior forces much better than rock of nearly uniform size. The statement that less damage would result from water leaking through the mass does not seem to justify the rejection of the quarry waste, as leakage, even if a considerable quantity of water passes, would not be harmful. There might be a local settlement, but, with the slopes adopted in the Morena Dam, it would not seem to be important. This remark refers

Mr. Galloway.



SECTION OF DAM AND DISCHARGE PIPES AT HIGHEST POINT

FIG. 7.

Mr. Galloway. to dams with a proper slope of the fill, and not to one of bad design such as the Walnut Grove Dam in Arizona.

The foregoing observations are not made as criticisms of the Morena Dam, for the writer believes it to be a structure of excellent design, on which Mr. O'Shaughnessy is to be congratulated for its planning and execution.

Mr. Hawgood. H. HAWGOOD, M. AM. SOC. C. E. (by letter).—This paper is replete with matter which is interesting and useful to those engaged in water projects. Through the courtesy of Mr. O'Shaughnessy and Mr. Moloney, the writer was afforded an opportunity to examine the structure minutely, and can testify to the thoroughness which characterized the work and the methods used.

The dam embodies in a marked degree two features essential to successful rock fill or earth dams, that is, an impervious, or practically impervious, face, with a pervious back. The writer agrees with the author in regard to the advisability of keeping the rock fill, behind the water-tight skin, clear of soil and open to free drainage. In his opinion it is questionable whether such settlements as may occur will cause the masonry face to leak sufficiently to warrant the contemplated concrete slab facing. It is improbable that such leaks will be other than small, or have any effect on the integrity of the structure, and such being the case, the stopping of leakage at an expenditure greater than the commercial value of the escaping water, would not be justified, and particularly as, in this instance, all leakage, save such portion thereof as would be lost in evaporation in traversing the intervening cañon, would be recovered by the Barrett Dam, 10 miles down stream. An absolutely water-tight dam and reservoir is an academic ideal, rarely, if ever, attained in practice. Seepage, or leakage, is of no particular moment, provided its possibility has been fully safeguarded in the design, and its magnitude be insufficient to become of commercial importance. The "dry" gate-tower and tunnel outlet, independent of the dam itself, remove a fruitful source of trouble.

The writer spent some time in the cable engine-room watching the working of the signaling apparatus, and being engaged at the present time in building a dam where the signals are conveyed by bells, was impressed with the superiority of visual over audible signals. With bells it is a matter of count, memory, and wakefulness, as to how many bell taps were given. With the visual signals, the call remains illumined until replaced by another, thus eliminating any element of uncertainty, and minimizing risks.

It would be of interest, in connection with the water-shed and rainfall, to know the discharge capacity of the spillway, and it is hoped that Mr. O'Shaughnessy will supply this information.

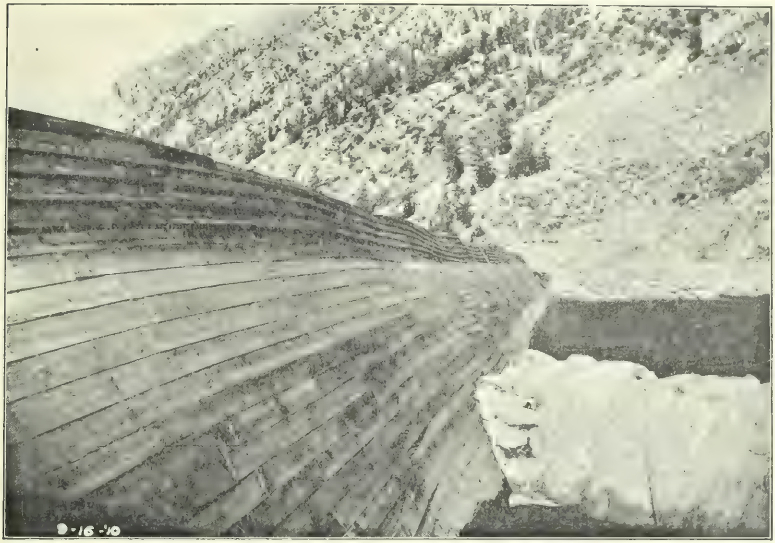


FIG. 1.—TIMBER SHEATHING OF ROCK FILL DAM ON MIDDLE FORK OF BISHOP CREEK, CALIFORNIA, FOR THE NEVADA-CALIFORNIA POWER COMPANY.

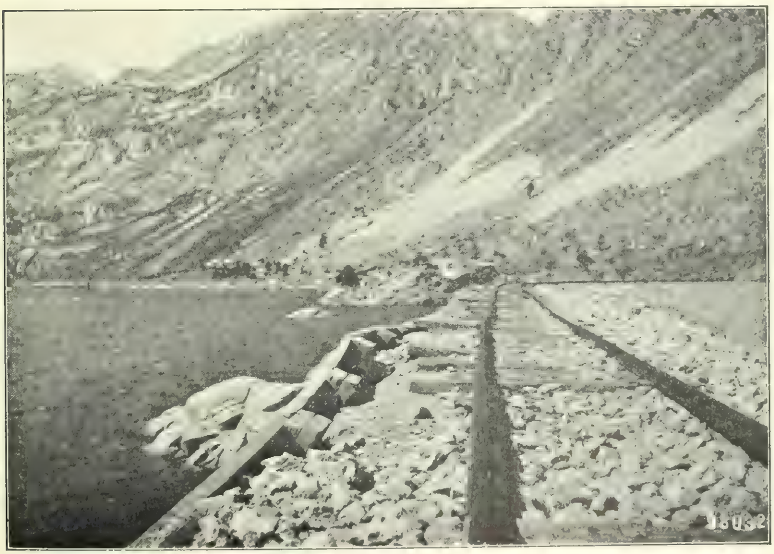


FIG. 2.—CREST OF TIMBER-FACED ROCK FILL DAM ON MIDDLE FORK OF BISHOP CREEK, CALIFORNIA, SHOWING CONSTRUCTION AND SETTLEMENT.

Mr. Hawgood.

The difficulty of deducing run-off satisfactorily from rainfall is well illustrated by the rainfall and run-off tables in the paper. With a precipitation of 12.79 in. at Barrett and 18.56 in. at Morena in 1907, the run-off was 2.62 times that of the succeeding year, with a precipitation of 16.82 in. at Barrett and 20.56 in. at Morena. Similarly, in Table 3, for the Sweetwater water-shed, 15.52 in. in the season of 1905-06 produced 2.54 times the run-off of the preceding season, with a precipitation of 15.55 in.

Applying Kutter's formula to the particulars of the Dulzura Conduit, as far as they are given, it would appear that the value of n approaches 0.02. It hardly seems probable that, with so smooth a conduit, the coefficient would be so low; perhaps Mr. O'Shaughnessy will throw some further light on this point.

Mr. Maltby.

F. B. Maltby, M. Am. Soc. C. E. (by letter).—This paper is especially welcome at this time, as the construction of many dams for various purposes and distributed widely over the country is in contemplation, and the disastrous results of some recent failures of such structures have brought into prominence questions relating to their design and construction.

The writer regrets that Mr. O'Shaughnessy did not discuss more fully the reasons for choosing this particular type, and especially for the dimensions and slopes used. It is hardly necessary to open a discussion on the relative results of the different kinds of construction: hydraulic fill, solid masonry, or rock fill. Each has its advocates, and its particular advantages in certain localities and under certain conditions.

It seems that, under existing conditions, cost of materials, etc., the type selected is probably the most suitable for the locality. The writer also thoroughly agrees with Mr. O'Shaughnessy as to the inadvisability of making a combination of a hydraulic and rock fill. Such a dam would have the particular advantages of neither type, and would possess the weak features of both.

One of the strongest arguments in favor of a rock fill dam, outside that of cost, is based on the feature of construction which permits of thorough and comparatively unobstructed drainage, and relieves the structure of the injurious effects of uplift due to leakage either through or under it, which was so prominently brought out by some recent discussion.

The writer does not see the necessity or desirability of the reinforced concrete slab facing. If he understands the drawings and description, the upper face of the wall, to a depth of 6 ft., was laid in mortar, and this wall certainly could have been made tight enough for all practical purposes. If, through settlement, cracks appear which permit an undue quantity of leakage, they can be filled or

Mr. Maltby. caulked at much less expense than by placing the proposed concrete slab.

It sometimes seems that, in the present age, when the use of reinforced concrete is advancing so rapidly, engineers are prone to introduce such construction unnecessarily. Even if it was desirable to cover the face of the dam with a concrete slab, the writer does not understand the line of reasoning used in determining the quantity of reinforcing steel.

As the slab is to be poured directly on the face of the wall, there is no unsupported space or span to be carried, and the only function of the reinforcing steel is to provide for expansion, and, as expansion joints are provided every 48 ft., the matter would not be a serious one.

If the steel is to provide for expansion only, why should there be more of it at the lower part of the slab than near the top? The change or variation in temperature at the top of the dam will certainly be greater than at the bottom.

Again, it is difficult to understand the utility or necessity of the anchor bars set into the backing on 4-ft. centers. Apparently, they extend into the backing about 3 ft. and into the slab about 3 in.

It is hoped that the author will state the reasoning used in determining the quantity of steel, especially as it must have been a very serious item of expense.

It is regretted that the author has not given as much and as exact information concerning the construction and detailed cost of the dam proper as is contained in the interesting descripton and cost of blasting the rock.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852.

PAPERS AND DISCUSSIONS

THE HALLIGAN DAM: A REINFORCED MASONRY STRUCTURE.

Discussion.*

By Messrs. Maurice G. Parsons, Lars R. Jorgensen, S. G. Swigart, Charles B. Buerger, and Maurice C. Couchot.

Maurice G. Parsons, Jun. Am. Soc. C. E. (by letter).—It is gratifying to see the arch dam gradually coming into favor, for, in the writer's opinion, the Profession has heretofore given in too easily to the views of the lay mind as to the stability of these structures. For generations engineers have successfully built arch bridges dimensioned by methods of analysis no more certain than those applied to arch dams. A satisfactory theory of investigating the stresses in bridges has but recently been developed, and dams designed by the arch formula can be investigated under combined arch and cantilever action. Mr. Parsons.

If properly designed and constructed, such dams can fail only by being undermined, overtopped, or actually squeezed to death, while, within certain radii, they effect an economy of material; are less subject to temperature and shrinkage cracks than straight dams; and horizontal joints in them are rather to be commended than condemned. Most certainly the Bear Valley and Sweetwater Dams—one the thinnest in the world, and the other proof by trial against severe spill shocks—should highly recommend the arch type. With the advent of concrete and the development of arches, the multiple-arch dam seems to be the ultimate masonry type.

In relation to the Halligan Dam, the arch formula, $T = r\ g$, gives a unit stress of 27 tons per sq. ft., or 375 lb. per sq. in., at Elevation 0, under the assumption of a 72-ft. head, which pressure is within

* This discussion (of the paper by G. N. Houston, M. Am. Soc. C. E., published in *Proceedings* for October, 1911, and presented at the meeting of December 20th, 1911), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Parsons. the bearing power of good masonry. Developed from a consideration of the simultaneous deflection under arch and gravity action, we have:

$$S_a = \frac{h^2\, x^2\, S}{2\, r^2\, b^2 + h^2\, x^2} \dots\dots\dots\dots\dots (1)$$

$$S_g = \frac{2\, r^2\, b^2\, S}{h^2\, x^2 + 2\, r^2\, b^2} \dots\dots\dots\dots\dots (2).$$

When $S = 62.5$, S_a and S_g are the numerators in fractions having 62.5 as the denominator representing the proportion of the total external force carried by arch and gravity action, respectively. In these equations: r = the radius, in feet; h = the head, in feet, to the bottom, where the width is b, in feet; and x = the distance, in feet, of the section in question above b. These formulas give a gravity action of 100% at the bottom. "Trimming," by reason of the stresses obtained from an investigation by these formulas, would not be good practice, the formulas being useful for investigation, but not for design. If provision is to be made for up-stream tension, the rational procedure is to determine its extent, and then design to meet it. Being developed on the supposition of a triangular section, the actual division of stress as given by these formulas is indeterminate in this case, and, accordingly, the author had to make assumptions. It is presumable that he formulated a good guess, and has the proper quantity of steel, at his safe unit stress, to care for the tension resulting from the line of pressure, reservoir full, falling without the central third of the base. The formulas show the danger of assuming a low total stress in the steel; if the cantilever action be enough greater than that assumed, rupture of the steel and failure as a cantilever will result.

With the gravity dam there is also the question of cantilever action, for masonry is elastic, and experiments prove up-stream tension in designs is supposed to obviate all but compressive stresses. As there are gravity and arch formulas, so a dam could be designed as a cantilever of uniform strength. Assuming a slice 1 ft. thick, its side elevation would be obtained as follows:

$\frac{S\, I}{c} = M = \frac{w\, h^3}{6\, d}$, in which S = the allowable stress, h = the head over the horizontal section, the section modulus of which is $\frac{I}{c}$ and w = the weight of 1 cu. ft. of water. In the case of a homogeneous material and a rectangular plan, $\frac{I}{c}$ is $\frac{b^2\, d}{6}$, when d = 1 ft., as in this case. Then: $S\, b^2 = w\, h^3$,

$$\text{and } b = \sqrt{\frac{w}{S}\, h^3} = k\, h\, \sqrt{h}.$$

A dam dimensioned by this, as by the arch formula, would have additional stability because of gravity.

Mr. Parsons.

In dealing with arches as generally constructed, there is not only arch, but also gravity and cantilever action. In spite of the fact that the arch theory is based on the assumption of rings which enable the dam, at any depth, to act as if an infinitesimal lamina existed, in practice, the thrust and resulting stresses at various depths must be integrated by the masonry. There is a question whether the use of steel, in hindering free laminal action, is justified.

Furthermore, considering the subject of steel in general, it may be remarked:

1. That the ancient metal upon which is based the belief that reinforcement will last forever, is of a different nature than the present steel.

2. Other structures are not subjected to dampness to such an extent as dams, and, therefore, the use of steel in them is more conservative.

3. Streams of Western America are often far from chemically pure, so that the corrosion of the steel used to hold them back may be expected.

4. Engineers have gone reinforcing mad.

In dealing with arch dams, it would seem best to go by the formula, $T = r\ g$. There may be additional stability for a time, because gravity and cantilever action will exist to a certain extent unless preventive measures be taken. After these actions give out, sole reliance devolves on the arch action, but the dam cannot then fail without being crushed. Some day horizontal cracks will form and the steel will give way, thereby destroying any cantilever action. Again, from its very nature, the arch should be constructed in laminæ. Then cantilever action will be impossible, or investigation thereof unnecessary, for separate arch rings can act independently, and internal stresses can be lessened.

The author is to be congratulated on the result: His dam is safe as long as the steel lasts, and, after that is gone, if it ever is, the structure will still be safe, even with horizontal cracks. He has built a monument, bold in its conception and yet entirely substantial, while, according to his figures, it has cost less and has risen higher than the dam originally designed.

Mr. Jorgensen.

LARS R. JORGENSEN, ASSOC. M. AM. SOC. C. E. (by letter).—The author states that the dam presents two novel features: the projecting spillway and the light cross-section. Of these two features, the projecting spillway is the best, and is a good solution of the problem. The cross-section is not too light, but the radius is unnecessarily long. The factor of safety of a dam, where dependence is placed on arch action, as in this case, is proportional to the thickness of the dam divided by the length of the up-stream radius; that is, just as much depends on the length of the up-stream radius as on the thickness.

With water to the top of the dam, 72 ft., the mean axial com-

Mr. Jorgensen. pression is practically 25 tons per sq. ft. of the cross-sectional area. While there are several dams in the design of which this stress has been used successfully, it is at present considered somewhat high, especially for a comparatively thin circular column like the Halligan Dam. If the Bear Valley Dam has a factor of safety of between 2 and 3, as it probably has, the Halligan Dam should have a factor of safety of 5, at least. With a dam, however, there is always uncertainty as to the penetration of the hydrostatic pressure into the body, and, therefore, the factor of safety should be extra high.

In the middle of the dam, cantilever action takes place, and the steel rods help the arch to carry the load, together with the compression, in a horizontal plane along the down-stream face. This cantilever action diminishes from a maximum at midstream to zero at or toward the abutments, for the reason that the deflection of the arch has its maximum value in the middle, between the abutments, and has no deflection at the abutments, because it is held there. If the arch does not deflect near the abutments, it does not give the vertical beam (the cantilever) an opportunity to help. The axial compression at and toward the abutments, therefore, will be very nearly equal to the full 25 tons per sq. ft., whereas, in the middle, the axial compression will be much less, because the steel rods in that neighborhood are given a chance to serve the useful purpose of holding down the up-stream face of the dam.

An up-stream radius of about 200 ft. would have produced a dam in which the material would have been better utilized. The most economical up-stream radius is equal to the width of the cañon divided by the constant, 1.84, and to this is added the distance from the center of gravity to the up-stream face. It is true that the longer arch requires more material, but the factor of safety is increased in a much greater proportion by using the shorter up-stream radius. Using the shorter up-stream radius, and the same quantity of materials (and therefore a thinner section), will give a stronger dam, as the material will be better placed.

Mr. Swigart. S. G. Swigart, Esq. (by letter).—The writer, who was the designer of the original gravity dam and had supervision of its construction up to the time when work was stopped owing to the financial difficulties of the irrigation company, wishes to make a few corrections.

Mr. Houston states that the cost of the work previous to his taking charge of it was more than \$100 000, and that about 3 500 cu. yd. of rubble concrete were in place. The fact is that the cost of the construction up to that time was just about \$92 000, and, by actual cross-sections, more than 6 000 cu. yd. of rubble stone concrete were in place.

The author fails to mention anything about the cost of the excavation, much of it in a very hard but seamy granite (at one point 43 ft.

leep in rock), mixed with a red talc formation which could not be hot out, but had to be picked out by hand; the cost of the diversion of the river; the erection of the plant; the stripping of the quarries; ınd the fact that more than 2 000 cu. yd. of rock were quarried ready 'or crushing, about 300 cu. yd. crushed, and about 1 500 cu. yd. of sand hauled to the works, ready for use. Nor does he mention the 'act that all lumber used for forms, scaffolding, falsework, buildings, camp, sand and cement chutes, crushed-rock bins, etc., and the cast-ron gates and raising devices were bought and paid for, hauled to the dam, and that one of these gates had been placed in position. Mr. Swigart.

The excavation was very difficult and expensive. It was under water, having been classed as wet excavation, and cost more than $26 000. The cost of the diversion of the river was about $1 000; freighting the material to place $4 500, and erecting the machinery (which was all left in place ready for use, and was used on the later work) $500. The cost of material left on the ground was about $12 000, and that of the gates and raising devices about $1 600, making the amount to be deducted from the total previously given, about $45 500, leaving for the concrete work proper approximately $46 500. Much of this work was 1 : 2 : 4 concrete, in such places as the cut-off wall under the heel of the dam, around the outlet tube, and 2 ft. thick over both faces of the entire dam. The bed-rock, which was very irregular, was first covered with a thick coat of 1 : 1 mortar. (This portion of the dam was all in the spillway section, thus being subject to heavy erosion on the down-stream face.)

The author may not have intended to convey a wrong impression, and his figures were probably based on incorrect information; but the writer feels that the statements herein corrected, would naturally give a false impression as to the actual cost of the work under his charge. Also, regarding the percentage contract, while the writer does not approve of that form of contract in general, the percentage (20%) was based entirely on the labor cost, the material, office, and engineering expenses being specifically excluded, leaving it as based on what was actually only 60% of the total cost; in other words, if figured on the total cost as a base, it was only 12 per cent.

The work was carried on by the contractors, The Walter Sharp Construction Company, represented by Messrs. Walter Sharp, the President, and J. P. Brackett, the Secretary-Treasurer, who were both on the ground and in charge of the work at all times, and conducted it in a faithful and honest manner. Considering all the difficulties encountered and the naturally greater expense of placing concrete in the foundation under a heavy head of water, as well as in the winter, with all the necessary additional precautions against frost, the work was handled with at least reasonable efficiency, and every bit of it was well done.

Mr. Swigart.

When the work was suspended for lack of funds, the contractors offered under bond to complete the remaining portion of the dam, which was simply a question of straight concrete work without further danger from floods, at a total cost of $75 000 for the dam complete, up to 10 ft. above the original plan. If their offer had been accepted, the dam would have been completed two years before it was finally finished, and the irrigation company would have had the benefit of two years' storage of water.

As to the design of the reinforced structure built on the foundation and portion of the original dam, while the writer does not agree with Mr. Houston as to the matter of assuming that the arch will carry all the strain not taken by the reinforced concrete calculated as a vertical cantilever beam, and would prefer greatly, especially with an arch of this radius (324 ft.), to be on the conservative side and make no calculation on the arch carrying any strain whatever, or, in other words, simply adding that much to the factor of safety, he does not wish to enter into a discussion of the design.

Mr. Buerger.

CHARLES B. BUERGER, ASSOC. M. AM. SOC. C. E. (by letter).—Any determination of the stresses in a dam combining the features of arch, gravity section, and reinforced concrete beam, presents uninviting difficulties, and Mr. Houston's attempt at this calculation for the Halligan Dam will be appreciated; but his method cannot be accepted as a satisfactory solution, and his figures do not represent the result of any logical method.

The safety of the dam is not questioned in this criticism, as it appears that the maximum concrete stress, taking the dam as an arch alone, is approximately 27 tons per sq. ft., which is moderate enough.

The author assumes for his purpose the position of the neutral axis and the stress in the steel. These two assumptions cannot be made simultaneously, as they are dependent on each other and one determines the other. Using his notation, these relations are expressed by the equation:

$$s = \frac{j - 0.5 - x}{x} \times \frac{E_s}{E_c} c$$

$$A_s (s + W) = \frac{x c}{2}$$

in which s is the stress in the steel,

E is the modulus of elasticity,

and A_s is the area of the steel in the section.

For the section at zero elevation, working back from the figures in the table, approximately,

$P = 81,$

$W = 77,$

$A_s = 0.00542.$

Mr. Buerger.

Then, assuming that $\frac{E_s}{E_c} = 15$, and $x = 10.6$, and solving, gives:

$$c = 18.85,$$
$$s = 2.95.$$

It appears that the assumption that the neutral axis is four-tenths of the distance between the compression face and the steel from the compression face as made, of itself fixes the steel stress at 2.95 tons per sq. in. instead of 6 tons, as assumed, and the tension per linear foot of dam at 2.3 tons, in place of 4.7 tons. The concrete stress becomes 18.85 tons, in place of 15.7 tons. The amount of this difference is not remarkable, but this is only because the steel present is so small in quantity as to be of little worth, and if the resisting moment is calculated, without considering the steel at all, the concrete stress of the gravity section increases only to 20 tons per sq. ft.

In a general way, the addition of a trifling quantity (here $\frac{1}{50}$ of 1%) to a masonry section, does not warrant a treatment of that section materially different from that accorded to a similar section without steel.

Mr. Couchot.

MAURICE C. COUCHOT, M. AM. SOC. C. E. (by letter).—This subject is one of much interest, due to the growing confidence of the Engineering Profession in the uses of reinforced concrete in dam construction. The writer was the pioneer advocate of its merit for building purposes in San Francisco, and spent much time in combating the opinions of those who were prejudiced in favor of adhering to brick construction, but its most enthusiastic advocate should take the greatest precautions to see that the cement, sand, water, reinforcing rods, and crushed rock, are of the proper standard to make a good mixture.

Concrete construction and the uses of cement have been growing rapidly during the past ten years, the domestic output of cement having increased from 8 482 000 bbl. in 1900 to 76 549 957 bbl. in 1910.

This has necessarily created a great many new cement companies, the personnel and product of which should be carefully scrutinized by the engineer who commits his reputation to the use of their products. It cannot be alleged that any company would deliberately be guilty of willfully turning out an inferior product which would only react injuriously on the manufacturer, but it must be admitted that many cement companies—new in the business—have had to go through the mill of experience in order to produce a cement which is safe for the engineer to use. In the writer's opinion, no cement should be placed in a building or structure until it had stood the 28-day test under the supervision of the engineer, and had been subjected to some independent testing, outside of the professional laboratories of chemists, either directly or indirectly associated with the cement

Mr. Couchot. manufacturers, and who are often recommended by the latter to the confiding purchaser.

Mr. Houston has not stated whether he submitted this Ideal Portland cement to any further testing than that of the Pierce Testing Laboratories at Portland, Colo., nor has he stated where or by whom the samples were obtained.

These pertinent questions are asked because of a parallel case in a dam being built, within the writer's knowledge, near Raton, N. Mex., where this same Ideal cement, with approved cement tests by Pierce, was found to be worthless, as shown by Table 3.

TABLE 3.—Pierce Tests of Ideal Cement.

Date.	Car No.	Tensile strength of neat cement, in pounds per square inch, at 7 days.
November 17th, 1910.....	15 673	600
December 26th, 1910......	5 638	515
December 28th, 1910......	4 980	470

After the concrete in which this cement was used was found to be worthless, average samples of the same cement were sent to the Laboratory of the Colorado School of Mines, at Golden, where it was tested by Professor William J. Hazard; the results are given in Table 4.

TABLE 4.—Hazard Tests of Ideal Cement

Date.	Water used.	Tensile strength of neat cement, in pounds per square inch, at 7 days.
February 17th, 1911........	New Mexico water.......	365 lb., 1st sample. 383 " 2d "
March 6th, 1911............	Golden water............	303 " 1st " 241 " 2d " 256 " 3d "

All the concrete in which this cement was used was found to be so porous and inferior that it had to be replaced with concrete made from a reliable brand of cement manufactured in Kansas, and the damage due to the defective cement is now a matter of controversy with the owners of the structure.

The point particularly desired to be emphasized by this discussion is the necessity for engineers to be vigilant and guarded in the inspection of cement and the extent of confidence they bestow on cement laboratories, the proprietors of which may be associated in some way with the factories; and, further, to have enough reserve storage of cement on the works to observe carefully the action under a 28-day test, at least.

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROVISION FOR UPLIFT AND ICE PRESSURE IN DESIGNING MASONRY DAMS.

Discussion.*

By Messrs. G. M. Braune, Edward Godfrey, Allen Hazen, Charles E. Waddell, Rudolph Hering, M. G. Barnes, Howard J. Cole, and M. H. Gerry, Jr.

G. M. Braune, Assoc. M. Am. Soc. C. E. (by letter).—This paper is a timely presentation of the subject of uplift pressure on masonry dams. Mr. Braune.

Assuming a solid rock foundation and a certain head of water, different designers will arrive at quite different sections, owing to the varying assumptions in their calculations. The width of the bottom of a solid masonry dam will depend on the position and direction of the resultant force, and if the intersection of this force with the base is kept well within the inner third, and the angle of inclination with the normal is small, the uplift force will be cared for automatically in the calculations. As it is probable, however, that the uplift force does exist, it is proper to provide for it in the design. Whether the full static head is exerted over the entire base or diminishes in magnitude toward the down-stream edge would depend on several conditions, namely, the nature of the rock formation, the character of the workmanship, the method of laying masonry, etc.

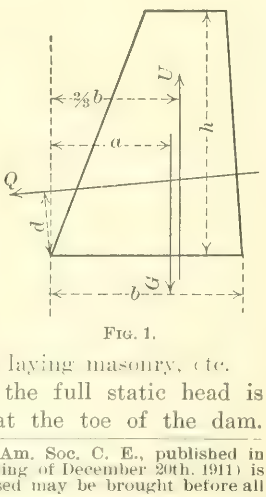


Fig. 1.

In Fig. 1, the assumption is made that the full static head is exerted at the up-stream edge and is zero at the toe of the dam.

* This discussion (of the paper by C. L. Harrison, M. Am. Soc. C. E., published in *Proceedings* for November, 1911, and presented at the meeting of December 20th, 1911) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Braune. This uplift force is then, $U = \frac{h\,w\,b}{2}$, in which $h =$ the head of water, $w =$ the weight of 1 cu. ft. of water, and $b =$ the width of the dam at the base. The resisting moment is $G\,a$, and the overturning moment from the lateral water force is $Q\,d$.

If an allowance of F is made for a factor of safety for the overturning moment of the lateral force, and the uplift is taken into account, then the equation for stability against overturning will be:

$$G\,a = F\,Q\,d + \frac{b^2\,h\,w}{3}.$$

In Fig. 2, in which the full static head is assumed, the equation against overturning will be:

$$G\,a = F\,Q\,d + \frac{b^2\,h\,w}{2}.$$

Whether the first or second condition is assumed in the calculations, how then should F be chosen?

In the design of structures of steel, reinforced concrete, and similar materials, the agreement among the authorities as to the size of the factor of safety is fairly uniform. Of course, in designing dams, this factor cannot be fixed so definitely, but, for the same conditions, there should be some uniformity.

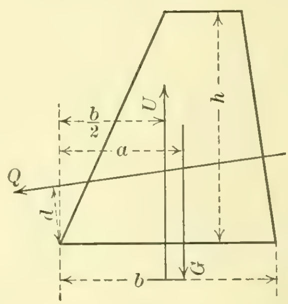


FIG. 2.

If this factor is assumed as 2, the base of the dam will be somewhere between 70 and 80% of the height in the first case, and in the second case, with full static head, 80 to 90% of the height. In the design of the dam at Marklissa, across the River Queis, in Prussia, the designer, Intze, assumed the full static head as acting over the entire base of the structure. The dimensions are: Width of crest 18.7 ft., base 123.6 ft., height 141.0 ft. It is founded on impervious rock.

Then, again, what should be the maximum deviation of the resultant from the normal? To provide for a small deviation will require a large base, if the full static uplift is assumed. Some designers require that the masonry should be built in alternate blocks of from 50 to 60 ft., in order to provide for expansion and contraction, while others ignore this requirement, and vertical cracks result. If these cracks are not harmless, why should the owners be subjected to the additional expense of alternate block construction?

It is to be hoped that, before discussion on this paper is terminated, many controvertible points in the design of dams will be thoroughly debated.

EDWARD GODFREY, M. AM. SOC. C. E. (by letter).—One of the most momentous questions at present before the Engineering Profession concerns the design of dams; not that it inherently possesses such serious problems, but that the question is a psychological one. When a large body of men is compelled to change any adopted ideas or standards, something must happen. Even in so simple and eminently useful a change as the adoption of standard time in place of sun time, bitterness and strife amounting almost to revolution accompanied the discarding of "God's time." Many towns for years had two or three standards of time. Thus far it has not been held that the (to date) general standard of designing dams is of divine origin, but something of the same fanatic opposition to discarding it has been heard from many quarters, in spite of the many lives which have been sacrificed to it and by it, as was heard when "railroad time" was on the rack; and compromises are suggested, as in the other case. Mr. Godfrey.

It is absolutely certain that engineers must revise their methods of calculating the stability of dams; the serious question is whether or not that revision will be thorough and complete, or will it for a season of years be a dangerous compromise to be completed only when another great disaster and the blood of other scores or perhaps hundreds of victims cry out? No future book on dams will commit the awful blunder of all English books written previous to the first failure of the dam at Austin, Pa.; no future book will omit entirely all mention of upward pressure on masonry dams. Surely no revisions can be expected to lay adequate emphasis on this omission; and it is doubtful if many new books will be written on the subject, as it is one which engages the active attention of only a few men. Furthermore, in some quarters, there is a tendency to belittle the real and demonstrable importance of the matter. The writer considers Mr. Harrison's paper an example of this tendency.

Railroad bridges could be built with no regard whatever for the dead load in calculating the strains. The majority of them would stand up and do service. Some of them would last a long time and never give the least sign of their inadequacy. Some of them, in fact, might never be over-stressed, as the assumed live load is usually in excess of any train load. There would be an occasional wreck, but as the fracture of steel is always sharp and crystalline in a sudden break, any required number of "experts" could be found to prove that the steel was burnt in the manufacture or crystallized in constant service. Just as experts of this class can always find a bad batch of concrete, a shaving, a block of wood, or some dirt in any reinforced concrete failure, so they can detect defective steel or workmanship anywhere.

If every book on the design of bridges omitted all mention of the need of considering the dead load, and gave examples of designing which ignored the dead load, and if some "destructive critic" should

Mr. Godfrey. come along and question the correctness of this, even maintaining that it was positively wrong and wreck-breeding, there would be the same hue and cry against this "iconoclast" that the under-pressure advocates have met; and he would be treated with the same silent contempt from some parties until those same parties had had time to get under cover gracefully.

It is as erroneous a proceeding to design masonry dams of any class without considering the under-pressure as to design bridges without considering the dead load; but it seems to be more disquieting to many to have accepted standards which have proven false than to have the Engineering Profession degraded by the periodic wrecks that these same false standards engender.

The foregoing is preliminary to this thesis: All masonry dams should be designed capable of withstanding upward pressure under the full area of the base, the intensity at the up-stream edge being not less than the full head. The writer will go a step farther and say that legislation ought to be passed requiring all masonry dams to be thus built, just as it requires buildings to be designed for dead and live load.

The wrecks which are occurring with such sickening regularity are writing against the Engineering Profession: *"Mene, Mene, Tekel, Upharsin."* It is time for the Medes and Persians to come in with some laws which cannot be altered. These three laws would have avoided nearly all the great structural wrecks known:

(1) Dams must be built to resist upward pressure.

(2) Structures must be substantially braced during and after erection.

(3) Concrete shafts must not be considered reinforced when they contain only slender vertical rods, even if these rods are wired together at wide intervals.

To be asked for a demonstration of the proposition that water exerts an upward pressure under the base of a dam and in horizontal joints is like being asked to demonstrate that the earth is not flat. To the writer's mind it ought to be all-sufficient if mere mention is made of under-pressure as a factor working against the stability of a dam. No demonstration is ever attempted to show that full water pressure against the up-stream face of a dam must be considered, though that face may be largely covered with mud and silt. One might make a paper demonstration which would show that a fillet of mud on the up-stream side of a dam would save a large quantity of masonry, and he would stand on precisely the same ground as the engineer who maintains that under-pressure may be neglected.

The failure of the Austin Dam, which occurred in September, 1911, has brought the subject forcibly before the Profession. Here

was a dam of standard proportions, which, by all the books on dams, was capable of withstanding the full pressure of the impounded water. It failed by reason of the pressure of water under it. This is just as clear and undeniable as the fact that the thing which causes the great force in a hydraulic jack is the small pump which exerts a pressure on a very small area of water. Mr. Godfrey.

Proof of the fact that water will exert pressure wherever it is confined and in communication with other water reaching to a higher head is too puerile to demand attention. Proof of the fact that there is water in the joints of a dam and beneath it, and that this water meets the last named condition, is equally puerile. Some one may say, in answer to this, "capillarity!" Is it capillarity which taxes the capacity of several steam pumps to keep unwatered the foundation of a dam during construction? Is it capillarity which causes water to well up in a spring apparently out of the solid rock? Is it capillarity which carries water a mile or more through compact earth and causes it to rise in wells or basements to just the height of the surface of a river in the neighborhood? Is it capillarity which causes water to flow out in jets through the joints of a dam, or to seep through the soil beneath a dam and force its way to the surface? Is that water discriminating enough to avoid the base of a dam in its passage? Is it capillarity which causes water to ooze out through a cast-steel cylinder (a little spongy) under great hydraulic pressure, when the same cylinder would be quite water-tight under ordinary high pressure? Is it capillarity which will eventually force out a tightly driven plug in the orifice of a house faucet, if the faucet should leak a few drops a minute? Was it capillarity which forced water under very low head through 30 ft. of solid concrete, as shown in the report of the Chief of Engineers, U. S. A., for 1902?* Is it capillarity which lifts the water-proof skin applied to a damp wall?

Mr. Harrison would have us believe that one of the easiest things in the world is to exclude water from a masonry wall, to place masonry on solid rock in such a way that no water will ever enter, and finally to find the solid rock without seam and of indefinite horizontal and vertical extent and to know of its existence before the excavation is made or the plans decided on.

In a recent book† occurs the following:

"Mr. J. B. Francis held that solid concrete deposited on bed rock would be lifted or floated, and to prove this, placed a pipe provided with a gauge, in the concrete of a dam and found that the gauge registered the full pressure."

---

* In *Engineering News*, April 2d, 1903, p. 306, Col. Peter C. Hains states: "This showed conclusively that there was less resistance to the passage of water through the 30 ft. of concrete than to its passage through the sandy material forming the earthen portion of the parapet."

† Beardsley's "Hydro-Electric Plants," p. 247.

Mr. Godfrey. The writer does not find a record of this experiment by Mr. Francis, but a test that amounts to the same thing is recorded,* in which practically the full pressure of water was communicated through 18 in. of carefully made cement mortar. When the pipe was left open, this same cement mortar allowed only about a bucketful of water to pass through in a day under a pressure of about 70 lb.

When engineers want to exclude water from a foundation, they cover the wall or ground with several layers of tarred felt. When they want to make a masonry cistern to hold water, they carefully line the entire inside surface with the same material. Do they ever line the up-stream face of a dam in the same way? Do they ever paper the bottom of a stream or lake?

Concrete can be made water-proof by making it wet and pouring it continuously; but the mortar used in laying ashlar or rubble masonry is not water-proof, because it must be a drier mixture in order to be handled properly and to set in a shorter time. This means that it has something of the properties of the old-style concrete, which acts more like a filter. Furthermore, the under side of a stone laid ever so carefully on a prepared bed of mortar will in all probability have many cavities. In some experiments by the writer in placing cast-steel column bases, grouting through the openings therein left large air spaces, as noted when the castings were removed for examination. It was only when the cement mortar was carefully mounded and the bases brought down with their first contact at the crest of this mound that these air spaces could be eliminated.

Efforts to prevent water from penetrating masonry walls are strenuous enough, in all conscience, to convince engineers that the only safe course is to assume that the water will penetrate a dam, and to provide for its maximum effect. Horizontal joints between two successive days' work in concrete are planes of entry for water. There are many evidences of this in copious leaks in walls and dams. The entire section of a concrete dam, therefore, should be designed accordingly, for such joints may or will always exist.

In a recent issue of a technical journal† there is a picture and a description of a concrete reservoir 100 ft. in diameter and 40 ft. high. Water is pouring out or has poured out of practically all the horizontal joints. The thickness of the shell is as much as 42 in. This reservoir was subsequently water-proofed by the expenditure of 900 bbl. of cement, 15 bbl. of water-proofing compound, 20 tons of steel, 500 cu. yd. of broken stone, and $11 000; and yet some builders of concrete dams will fondly imagine that no water ever penetrates the concrete or ever exerts any pressure beyond the line defining the up-stream surface.

---

* *Transactions*, Am. Soc. C. E., Vol. XIX, p. 147.

† *Engineering Record*, August 19th, 1911.

It is true that seepage of water through concrete will act to seal up the pores through which it passes. This is not a filtering action, necessarily, but may be purely chemical. It is possible, and in fact probable, that the action begins at the surface which is farthest from the water. This would supply exactly the condition that would intensify the pressure. It is entirely possible that the water would evaporate on the surface of the concrete as fast as it seeps through, so that no leak would be apparent. A porous surface is an admirable one to promote evaporation. In southern countries this principle is utilized to keep water cool. Porous earthenware jars containing water are hung up in the breeze so that the evaporation of the water which works through will cool the contents of the jar. Mr. Godfrey.

Dams have been classified in the matter of height and alleged cause of failure, with a view of showing that under-pressure is not responsible; but one thing is strangely absent in these classifications, namely, information showing that any of them would be stable against this under-pressure. A boulder will lie on the bottom of a river and remain stationary against its current. The fact cannot be gainsaid that a solid block of concrete laid on the ground may be made to hold back water on one side of it, though it may rest in ordinary mud. Failures of foundations are exhibited by sinking; failures of dams are usually shown by the sliding of large blocks after they have been lifted and lubricated by water under them. The character of the foundation has little to do with the existence of the under-pressure or the need of providing against it; though if failure takes place, due to under-pressure, it will be more complete and disastrous if the foundation is soft and yielding than if it is a solid rock. It may be even true that one dam designed without regard to under-pressure and built on a solid rock will stand up, whereas another built on a poor foundation, also designed without regard to under-pressure, will fail. This cannot be construed as an argument for disregarding a fact. Analogous to this, it is quite possible that one bridge designed regardless of the dead load will stand, whereas another, of longer span, will fail. In the case of bridges, the dead load in the long span is of greater importance because of larger amount, both relatively and absolutely. In the case of dams, the under-pressure on the dam resting on yielding soil is of greater moment because concentration of the pressure on a yielding base is more apt to cause failure, also because the softer soil will allow freer sliding. In neither case can the lesser menace be disregarded with impunity or with reason.

One of the arguments which is supposed to show that, of the 30 or 40 masonry dams which have failed in the last 20 years, under-pressure has not been the cause, is the fact that blocks generally slide out and do not overturn. When under-pressure, assisted by the horizontal

Mr. Godfrey. pressure, has pried a dam loose, the former has spent the greater part of its force. It would require time in order to gain a new momentum, as the water can enter but slowly in a narrow slit. The escape of a very small quantity of water in a test under great hydraulic pressure drops the gauge pressure very quickly. In the case of the dam, there is the ever-present horizontal pressure, with practically unlimited volume behind it, and this quickly acts to force the dam out in a horizontal direction.

Cut-off walls are a delusion and a snare, except for the legitimate use of reducing loss of water. They do not inhibit under-pressure, for water may pass through a long and circuitous course and, at the end of the same, if confined, exert its full pressure. A certain dam* had two cut-off walls, one 8 ft. deep at the up-stream edge and the other 5 ft. deep at the down-stream edge; it was completely underwashed. Another dam† had two cut-off walls, the deeper one being at the down-stream edge; it failed by under-pressure.

Under-drainage is another broken reed. To be effective, the whole dam would have to be honeycombed, and much water would be wasted. It is also likely to silt up or freeze and be rendered useless. Furthermore, it would be expensive. The same amount of money spent for additional concrete would be of more lasting good.

Anchoring into the rock to make up for deficiency in stability is another feature which ought to be condemned most severely. It is very difficult to anchor an ordinary rod in rock for its full tensile strength, and it is impossible to ascertain whether or not it is thus anchored.

For seven years the writer has been endeavoring to bring the subject of the design of dams before the Engineering Profession in an effort to break the solid front presented against safe design. He earnestly hopes that the agitation which the Austin failure has evoked will result in the complete rejection of the insane and unsafe method —the general standard which ignores under-pressure—and the adoption of the only safe and sane course, namely, to design all masonry dams for under-pressure, irrespective of the opinion of the designer. A designer's opinion never yet has sustained a weak structure. The more correct rules are adopted, and the less need for individual opinion, the safer will be the results.

Mr. Hazen. ALLEN HAZEN, M. AM. SOC. C. E. (by letter).—The existence of upward pressure under a dam depends on the relative perviousness of the material under it at different places, rather than on the absolute quantity of percolation. The cut-off works under the heel of the dam may be nearly tight, but they will never be entirely so, and if there

* *Engineering News*, April 1st, 1909.

† *Engineering News*, January 13th, 1910.

happens to be some place down stream where the material is entirely tight, seepage through the cut-off, however slight, will result in the production of a pressure under the base of the dam, equal to the full static pressure of the water in the reservoir. Of course, this extreme case is not to be expected, but the material under the toe may be less pervious than that under the heel, and, in that event, the pressure under the dam may be a considerable proportion of the whole static pressure of the water. Mr. Hazen.

If the material under the dam is obviously open and pervious, or has seams, the construction of a cut-off under the heel seems desirable and necessary, and, of course, it should be made as nearly water-tight as possible; but how is the engineer to know that there is not another place down stream, where the material may be sufficiently impervious to hold back whatever seepage there may be through the cut-off, and thereby produce upward pressure under the dam?

The same line of thought, of course, applies to any point in the body of the dam with respect to the masonry in that part of it below the point. Even though special care is taken to make the masonry near the upper face as impervious as possible, it may happen that, sometimes, some other place will be less pervious. Perviousness is not sufficiently under the engineer's control to prevent this from happening. In so far as it does happen, internal pressure will result, which is, in effect, upward pressure on that part of the dam above. Making the upper face of the dam as nearly water-tight as possible, and building cut-off works under it, may generally render this part of the work less pervious than the rest, but it cannot be safely depended on to do so in all cases.

A further line of defense is desirable, and is usually possible. This consists of drainage channels to facilitate the flow of water from the down-stream part of the dam, and from the rock under it. If such drainage can be made sufficiently comprehensive and certain in its action, it eliminates the possibility of upward pressure at any point controlled by it.

It is easy to build drains vastly greater in carrying capacity or perviousness than the part of the dam near the upper face and the material under it. Such drainage has been carried out in many dams. In the Cataract Dam, for the water supply of Sydney, Australia, the upper face of the masonry, to a depth of 2 or 3 ft., was built with especial care, and this alone was relied on to hold the water. The remainder of the dam was built of good, though more pervious masonry, and throughout the whole of it were placed 6-in. rectangular conduits, filled with broken stone, parallel to and about 6 ft. back from the up-stream face. These are collected into 6-in. earthenware pipes, laid at right angles to the longitudinal axis of the dam, with exits on the down-stream face.

Mr. Hazen. In the Ashokan Dam, of the New York water supply, open passages, of sufficient size for men to pass through and observe the conditions existing in various parts of the structure, have been left.

By eliminating the possibility of upward pressure, this system of drainage adds greatly to the stability of the structures protected by it, and it would seem well to apply it to all large masonry dams, depending mainly on their weight for stability. In small dams, it is relatively more difficult to apply it, and the protection is less complete, because there is a certain minimum distance from the upper face within which drains cannot well be extended, and this minimum is a larger percentage of the whole thickness of the dam when the structure is not large.

In short dams, also, it may be easier to brace against the rock sides of the valley as arches, and make them strong enough in this way, rather than carry out special precautions against water pressure below.

It is especially interesting to note that the late James B. Francis, Past-President, Am. Soc. C. E., in a paper* presented May 16th, 1888, discussed the need and advantages of drains to prevent the occurrence of water pressure in and under dams, and advocated the use of such drains. After the lapse of more than twenty years, little can be added to what he then said, from a theoretical standpoint; but, in that time, there has been experience with a number of dams, which adds force to the statements then made.

Mr. Waddell. Charles E. Waddell, M. Am. Soc. C. E. (by letter).—This timely paper is most suggestive. Those who have followed the discussion of masonry dams appearing in recent numbers of the technical papers must have been impressed with two things: First, the wide differences of opinion as to whether or not under pressure is to be considered; and second, that nearly all writers confine their discussion to dams of the reservoir type. As to the question of under pressure, opinion appears to grade down as evenly as the pressure itself, from the conservatism of John R. Freeman, M. Am. Soc. C. E., who would consider the entire pressure acting uniformly under the whole dam, to the extreme of Edward Wegmann, M. Am. Soc. C. E., who disregards under pressure where the foundation is at all trustworthy, and cites as examples a number of dams now standing. One writer states that five or six high dams have failed in the last ten or twenty years. From very meager statistics the writer finds the record of some thirty overflow dams in the same period. The average height of these dams was, perhaps, from 30 to 40 ft. Just why the greater number is of this type and size is purely conjectural. It may be that the failures are proportionate to the total number of the two types which have been

* "High Walls or Dams to Resist the Pressure of Water," *Transactions*, Am. Soc. C. E., Vol. XIX, p. 147.

Mr. Waddell.

built; or it may be that fewer high dams fail, owing to superior engineering and construction in works of greater magnitude, or that the forces tending to destroy the overflow dam are greater and more numerous than those acting on the high reservoir dam, and are less appreciated and understood. It may be pointed out that a dam with a surcharge has to contend with at least three factors peculiar to itself: First, the possibility of a vacuum caused by the sheet of falling water; second, the shock and vibration of the water in motion; and third, the effect of the body of water at the toe, which, assuming penetrability of the masonry, may tend to cause flotation. It is generally conceded that the first and second factors can be counteracted to some extent by giving the down-stream face of the dam the shape of the under side of the sheet of water at the maximum expected surcharge. In theory this would be a parabola; but in practice the end sought is obtained by giving the masonry easy curves of varying radii approximating the calculated parabola. If there are any uneven internal stresses in the masonry caused by temperature changes, retarded rate of cement setting, etc., the jar and shock of the falling water would seemingly be a most plausible explanation of some failures. In some dams of the overflow type recently built, the weight or holding-down effect of the falling sheet is stated to have been considered, together with the back pressure of the water below the dam. This last appears reasonable; but to pin any faith on the weight of the falling sheet would seem illogical, if the face of the dam is virtually the path of the particles of water in motion.

The wide variance of opinion as to what factors bear on the design of dams; the undeniable qualification that such a structure should be safe; and the further equally necessary stipulation that the cost be not prohibitive; all suggest the desirability of the Engineering Profession coming to some general agreement as to what constitutes safety, and deciding, as far as generalization is possible, the factors and limits governing conservative design.

While it is probably a mere coincidence, and is not even suggested as anything more, in a number of hydro-electric plants where the dam is approximately 35 ft. high, the writer has observed that the cost of the dam averaged about $20 per developed horse-power, as compared with perhaps $10 for water-wheels and $10 for electric machinery. Following Mr. Freeman's policy of designing for full hydrostatic pressure under the dam, it is not at all improbable that the preliminary estimates would have indicated the project as too costly to be remunerative, whereas the dams are standing and the plants are earning a fair return.

Two features of the present controversy are regrettable: the desire in some quarters to blame the corporations for insecure structures, and the clamor for political supervision of dam construction. There

Mr. Waddell. may be some companies which are avaricious to the point of taking a gambler's chance in order to save a few dollars, but, in all the dealings the writer has ever had with a corporation, he has yet to meet the case where greed has mastered sound reasoning; and if an engineer is so unfortunate as to be placed in such a predicament he can resign; nobody can force him to do wrong; hence the writer cannot see where the blame attaches to the corporations.

The writer suggests the wisdom of proceeding with great caution in endorsing, as a Society, or as engineers, the appointment of any State boards or commissions to pass on dam construction. Our national panacea for any and all evils is legislation; but since engineers, as a body, are not agreed on the salient features of dam design, it is expecting too much, is it not, to hope that a commission could strike the happy mean by which the public would be secure and the owners of a dam not suffer from excessive cost?

In closing, it may be pointed out that while many engineers, including the writer, are prejudiced, perhaps unreasonably, against the reinforced concrete dam, certainly the discussion of the present time strengthens the position of the advocates of this type of construction.

Mr. Hering. RUDOLPH HERING, M. AM. SOC. C. E.—Mr. Harrison's suggestions are so complete, and Mr. Wegmann* has explained the subject so fully, that it is difficult to add much to the discussion.

It has always seemed to the speaker that the two questions depend entirely on local conditions. There are cases where neither uplift nor ice pressure need consideration, and there is no doubt that under some circumstances they are exceedingly important.

The modern tendency is to look out for the upward water pressure to a greater extent than formerly, because of the exercise of this pressure through open seams. The remedy in the case of a dam is proper drainage, and this can generally be provided in a simple and effective way. The upper side of the dam should be made as water-tight as practicable, in order to prevent water from entering, but if any should enter the main body, it should be given an opportunity to drain away and not produce the otherwise resulting upward pressure. This drainage should be provided for the body of the dam as well as for its foundation, should this be necessary.

There has been more experience, perhaps, in the effects of this upward pressure in reservoirs than in dams. The bottom of a small reservoir built on one of the Hawaiian Islands was lifted and broken by such pressure. This result was due to percolation through coral rock, which, according to all appearances, should not allow much

* The revision of Mr. Wegmann's oral discussion has not yet been received; it will appear in a subsequent issue of *Proceedings*.

water to pass through except in very small channels. A very fine stream of percolating water, however, if it is free to move, is sufficient to exercise this upward pressure. It is the same old phenomenon which by the Greeks was called the hydraulic paradox, when it was realized that by a very small quantity of water a very large pressure could be produced. Mr. Hering.

M. G. Barnes, M. Am. Soc. C. E.—The discussions on Mr. Harrison's paper have been confined to the foundations and the upward pressures under the dam at the foundation; but, some points which were not mentioned appeal to the speaker as having great weight in the design and construction of concrete dams. Mr. Barnes.

In depositing large masses of concrete, horizontal joints are frequently permitted; in fact, even if prohibited by the specification, it is not always possible to avoid them, because storms, failure of plant, failure of delivery of materials, etc., may make such a joint necessary, and at a very undesirable plane. Moreover, in the methods frequently practiced, very wet concrete is deposited, and large quantities of water are permitted to accumulate on top of it. This water carries the inert matter and laitance from the sand and cement, which is deposited on top of the concrete. The speaker has seen such a deposit fully 1 in. thick, with new work built directly on it. This deposit prevents any bond between old and new work, and allows hydrostatic pressure to take effect at the joint. It may be argued that such work should not be permitted, and that the laitance should be removed. It is well enough to lay down drastic rules in the specification, but the designer or consulting engineer is not usually the constructing engineer, and his orders are not always carried out. Therefore, such poor construction must be taken into consideration in the design.

If, under these conditions, the full upward pressure, as has been suggested, and the high ice thrust are assumed, in addition to the ordinary horizontal pressure, absurd results will follow. For example, take the condition mentioned by Mr. Brodie,* but consider a spillway section with water and ice just at the coping level. Assume a full upward pressure on the joint which is 10 ft. below the coping, and a horizontal ice pressure of 21 500 lb. The speaker has computed the stability of the dam under these conditions, and, unless he has made some mistake, the weight of the masonry above the 10-ft. joint is approximately 18 500 lb. This is less than the assumed horizontal pressure of the ice alone. Assuming a full upward pressure, the effective weight of the concrete is only about 8 200 lb., and its resistance to sliding, using a coefficient of 65%, is 5 330 lb.; but the sum

* The revision of Mr. Brodies' oral discussion has not yet been received; it will appear in a subsequent issue of *Proceedings*.

Mr. Barnes. of the assumed horizontal pressures is 24 625 lb., or about 4.6 times the resistance of the dam. In other words, the dam would have to be about 50 ft. wide at the spillway in order to balance the sliding forces. Manifestly, the conditions assumed are not realized in practice. It is just as reasonable to make these assumptions for the horizontal joints as for the base of the dam; in fact, the bond between the rock and the concrete is better than at the joints.

Mr. Gregory has assumed that the water stood at the elevation of the coping, and has discussed a joint 10 ft. below. If it is assumed that the dam is built 10 ft. above the ice pressure, then the only pressure exerted on the dam at 10 ft. below the coping, is that from the ice, and the total force tending to slide the dam is 21 500 lb., while the resistance to sliding, assuming a coefficient of 65%, is 12 000 lb.

Mr. Cole. HOWARD J. COLE, M. AM. SOC. C. E. (by letter).—In the design of a masonry dam, the necessity for making provision for ice pressure is more theoretical than practical, as witness the many dams now in use for which such provision was not made; the designer doubtless being influenced by the fact that as the body of water impounded by the dam would have sloping shores which would care for the expansion of the ice, the vertical face of the dam would form a very small proportion of the shore line, and provision for ice thrust need not be considered.

In one large dam, the impounded lake is about 30 miles long, making an approximate shore line of 60 miles, of which the dam itself forms some 1 200 ft., or about $\frac{1}{263}$. This same condition is true in the case of most large masonry dams, though not in this ratio, and it is seen that, except where the shores are vertical, Nature has amply provided for the expansion of the ice.

An important feature which has a decided bearing on the necessity for a provision against uplift, and is frequently seriously neglected, is the need of a careful exploration of the subsurface condition of the dam site before designing the structure.

The mere fact that rock crops out along the dam site is no assurance that the location is a proper one on which to build. Core borings should be taken at frequent intervals over the site extending well down into the bed-rock (the depth varying with every location, and depending on the geology of the country), in order to develop fully the character and stratification of the underlying rock.

In a limestone country, the rock is likely to be permeated by cavities and subterranean passageways which would be disastrous to a dam built over them, and would surely cause some uplift, for which provision should be made by completely filling the voids with grout and concrete, and adding to the dam section.

A proposition to build a dam in a region similar to that above described was reported against for the reason that the passageways

(discovered by careful investigation) proved to be so numerous and of such large section that it was not feasible to construct a safe dam for the proposed expenditure. Mr. Cole.

There is now under construction an important dam in a limestone section where considerable trouble has been caused by these same conditions, and a large expenditure is being made to discover the subterranean cavities in order to fill them with grout.

Sandstone, because of its nature, is likely to be very porous, and, with its seams and strata, affords a poor foundation unless provision is made to eliminate these dangers. A careful system of borings at the site of the dam at Austin, Pa., would have disclosed the porosity of the work, and would have prevented the disaster, as suitable provision would have been made in the design to counteract the conditions imposed by poor foundation rock. Too much emphasis cannot be placed on the necessity for careful preliminary subsurface exploration.

M. H. Gerry, Jr., M. Am. Soc. C. E. (by letter).—Mr. Harrison has clearly stated certain elements to be considered in connection with the design of masonry dams. "Uplift," as commonly used, refers to the vertical force acting upward under a dam or on some plane of cleavage in the structure itself. This force results from hydrostatic pressure either from the head-water above or the tail-water below the dam. There have been failures of dams caused by high back-water at times of flood, and as this condition is common to many structures, it should be considered. The author has referred to "uplift" as produced only by pressure from the head-water, but where there is considerable submergence of the masonry by back-water, a substantial force results therefrom. The uplift resulting from the pressure above can be reduced and limited very materially by the proper design of the structure itself. Every important masonry dam should be provided with a thorough system of drainage; and this should include the masonry, the foundation contact, and the bed-rock to a considerable depth. All drainage water, and especially that from the bed-rock, should be brought into a chamber or tunnel extending through the dam where the flow can be observed and its quantity determined. A complete drainage system adds but little to the cost of an important structure, and, if properly designed, it will prevent heavy uplift, which otherwise may result from pressure above the dam. The uplift from water below the dam cannot be limited in this way, and should always be considered with the other forces. Mr. Gerry.

Even in the author's Case (1), where the foundations are hard and sound, drainage should be provided, in order to limit the upward pressures. There is no such a thing as a water-tight foundation in the sense that sufficient water will not pass to produce pressure, and the only way to prevent this is to give the leakage a free discharge.

Mr. Gerry. In the author's Case (2), where the bed-rock has horizontal seams and there is a fall or rapids below, it is assumed that the uplift will be equal to the static head at the up-stream face, and zero at the heel of the dam. This is hardly a safe assumption. It is better to drain the structure and the bed-rock artificially, first having prevented, as far as possible, all leakage through the rock by a deep and well-constructed cut-off wall, and by grouting with cement the bed-rock itself. The small remaining leaks can then be brought out through suitable drainage pipes and but little uplift will result from the head-water pressure. The same remarks apply to the author's Case (3), save that it is well to observe that the full static pressures should always be assumed for a limited area of the base adjoining the up-stream face of the dam, and the pressure due to the maximum head of water below the dam should be assumed as acting on the remaining area of the base.

The preparation of the bed-rock is of the very greatest importance, and the judgment of the engineer must here be conclusive. As a rule, important dams should be deep seated into the rock and not merely placed on the upper surface. As far as possible, the masonry should be made one with the foundation rock, so as to avoid large and well-defined areas of cleavage. To accomplish this, it may be necessary to excavate the bed-rock to different depths. The author has well said that thorough investigations of the bed-rock at the site should be made by borings and otherwise. If the rock is at all soft and seamy, it should be investigated by borings to great depth, and should be tested for tightness by applying water and air pressure to the drill holes. If the dam is to carry considerable head and the rock is found not to be thoroughly tight, then it should be sealed with cement grout forced in under pressure; this operation being repeated until test holes show that it is substantially tight, after which drainage holes should be drilled into the rock for a moderate depth, and these holes should be piped and connected with the drainage tunnel. In the case of seamy rock foundations, a deep cut-off wall is of the utmost importance, and there is no reliable substitute therefor. If the rock is soft, the excavation for the cut-off can best be made with a channeling machine so as to avoid disturbing the adjoining rock. The grouting of the bed-rock, previously referred to, can be done with advantage after the cut-off wall is in place.

Every large dam should be provided with a reasonable number of vertical joints. The writer prefers to call these adjustment joints rather than expansion joints, because their principal function is to take care of the adjustment which takes place in the dam as a result of the setting of the concrete and the establishment of final temperature conditions within the body of the masonry. In a massive structure. such as a great dam, it requires a very long time (it may be

years) before permanent conditions are established. Changes of atmospheric temperature have but little effect on a massive dam, except near the surface. In some cases, in very cold climates, and especially if there is no water flowing over the dam, it is well to reinforce with steel near the surface in order to prevent local cracking, which, followed by the entry of water and repeated freezing, may otherwise injure the surface. The adjustment joints, however, serve an entirely different purpose, as they take care of the shrinkage of the concrete and prevent cracks running in irregular directions through the masonry, which otherwise are certain to occur. In cold climates, ice pressure should always be taken into account. In an important structure it is not safe to assume that the ice can be kept clear of the dam by maintaining an open trench. The right thing to do is to assume the full pressure equal to the crushing strength of the ice applied at the points where it will rest after the dam is in service. In designing a dam, all the forces acting should be taken into consideration, as in any other engineering structure. If this is done, and proper attention be given to the workmanship, the materials of construction, the preparation of the foundation, and the various details of design, there is no reason why structures of this kind should not be among the most enduring built by man. Mr. Gerry

Vol. XXXVIII. JANUARY, 1912. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

HOW TO BUILD A STONE JETTY ON A SAND BOTTOM IN THE OPEN SEA.

Discussion.*

By Messrs. L. M. Haupt, Frederic V. Abbot, John Taylor, Morton L. Tower, and Howard J. Cole.

Mr. Haupt.

L. M. Haupt, M. Am. Soc. C. E. (by letter).—It would seem that, after many centuries of practice in building structures of this important class, there should be little to be learned, and yet the author states in his opening paragraph that the art has been developed to a high stage only within the last 25 years, in the United States, and he proceeds to show the most economical order and proper dimensions and materials for the construction of works exposed to the violence of the sea. In view of the large deterioration, and the tentative methods which have been followed, it would appear that his analysis of the requirements is timely, and may serve a good purpose for the tyro who may be willing to be guided by the experience of his predecessors.

In ancient days, when ships were propelled by the winds, or triremes were driven by slaves, the depth of water over bars was of comparatively little importance, but, with the evolution of the ocean liner, requiring a clearance of 40 ft., the problem has assumed a world-wide significance; and jetties, as well as moles and breakwaters, have become essential as aids to navigation and elements for the salvation of life and property. The cost of these extensive structures, however, may be prohibitive, and, if numerous, may become a serious drain on the exchequer of a country, especially where the commercial development

*This discussion (of the paper by Henry C. Ripley, M. Am. Soc. C. E., published in *Proceedings* for November, 1911, and presented at the meeting of January 3d, 1912) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Haupt. is in its infancy, as in many undeveloped colonies requiring aid from the mother country. The policy of appropriating small sums for partial constructions, with intervening suspension of works, leaving them unprotected and exposed to violent storms, necessarily adds greatly to the cost and reduces the possibility of securing the channels desired. This has made it necessary to proceed tentatively, building a little at a time, and at first with submerged profiles, then to low water, followed by mid-tide, and finally to above high water, to secure the desired control. In cross-section, also, a similar progressive policy has been pursued, and the hearting has been placed on mattresses of brush laden with small stones and covered with larger rubble or rip-rap, with but little attention to the relation of the foundation-sill to the superstructure or the protection of the exposed ends of the work, subjected to violent wave or current action, with the result that the reaction of the jetty at its end invariably scours out the bottom, and makes it necessary to supply rock for the sand *in situ,* at much greater cost.

Efforts to reduce the cost by depositing clay or dredged material in the hearting, to render it more impermeable, have also resulted in disaster and added expense, and by adopting too great a height and width above high water, greater pressure and resistance have been offered to the maritime forces, with consequent greater deterioration.

All these elements the author has carefully considered, and the conscientious observance of his suggestions should result in great economy because of the more rapid and stable execution of the works. It does not seem to be necessary to point to specific instances of failures as indices to the conclusions reached, for the author's reputation as an experienced engineer, for many years in the service of the United States on the Gulf of Mexico, as a Member of the Board to design the great sea-wall at Galveston, Tex., and as Consulting Engineer for some of the principal harbors in South America, is a sufficient warrant of his competency to formulate the most desirable method of procedure for structures of this class; but, the works of the Phœnicians some 3 000 years ago, when they established harbors and ports on the coasts of the Great Sea (Mediterranean), especially at Tyre and Sidon, which are celebrated to this day,* indicates that there have been others skilled in the art of building sea-walls and jetties.

The insular Tyre was about one-third of a mile from the shore, with which it was connected by Alexander the Great, when besieged about 383 B. C. Strabo states that the walls were 150 ft. in height and correspondingly thick, and were built of massive blocks of stone bedded in mortar. Nebuchadnezzar had failed to take it after a siege of 13 years, but Alexander tore down the portion on the main land,

* Plans of these may be found in Edward Cresy's "Encyclopædia of Engineering," 1847.

Mr. Haupt.

and with its stones built the mole 200 ft. wide to the island. Cresy says:

"A violent storm of wind arose, and destroyed a portion of the work, * * * [no unusual experience]. This was speedily repaired, by causing large trees, cut down in the mountains, to be thrown in, with their branches entire, on which was heaped a quantity of earth, to render it strong enough to resist the violence of the sea."

Over this he advanced his battering rams, and the siege was on in earnest. The insular Tyre, destroyed by Alexander, is now a "place for the spreading of nets in the midst of the sea," as Ezekiel prophesied. The mole which the conqueror raised was washed away by a storm, and thus the peninsular Tyre was destroyed. The 9th Edition of the Britannica states: "The mole which he constructed * * * has been widened by deposits of sand, so that the ancient island is now connected with the mainland by a tongue of land a quarter of a mile broad."

Mr. Abbot.

FREDERIC V. ABBOT,* M. AM. SOC. C. E. (by letter).—This paper is peculiarly interesting to the writer because the procedure recommended therein is almost exactly that adopted at Charleston, S. C., in the years between 1884 and 1890. At that locality log mattresses formed the sub-foundation of the greater part of the jetties, but an apron of spalls and small stone, in lieu of logs, was adopted in some parts of the work, and proved thoroughly reliable and easy to construct; it was furthermore exempt from injury by the teredo. The original foundation mattresses, however, where promptly covered with 2 ft. of spalls, have given no signs of deterioration in the past 25 years.

The writer would emphasize the desirability of incorporating some large 1-ton to 7-ton blocks in the hearting. It adds stability to the core during construction, and, after completion, a tearing away of parts of the outer skin of heavy blocks by storms does not produce a general disintegration of the whole structure near the injured parts due to the washing out of long stretches of the core.

One advantage of such incorporation is that this use of large stone makes it possible for the engineer to conduct the work so as to utilize at all times the whole output of the quarry; in this way the costs at that end of the line are much reduced.

A jetty with a spall foundation and a superstructure formed simply by the deposit of regular quarry run along the axis, or a little to the seaward of the axis, is in some situations cheaper than one built to predetermined cross-sections, because the action of storms will show automatically where the wave action is a maximum, and where it is not so great. Points at which the waves knock down the original

* Colonel, Corps of Engineers, United States Army.

Mr. Abbot. superstructure are evidently the loci of specially severe attack, and by raising these portions a second, or third, or fourth time, or increasing the size of the stones used, all material is placed just where it is needed, and none is wasted in building up a theoretical cross-section which may be stronger than is required. In any jetty it is well if possible to delay the final covering with the largest blocks until there has been time enough for ocean waves to develop weak spots.

At Charleston the foundation was built out from the shore, but the outer ends of the superstructure were completed first and were extended toward the shore until surveys showed that sufficient concentration of ebb flow had been secured to give the depth desired in the jetty channel. To avoid the formation of a sinuous channel—hard to navigate—scour was directed by dredging, but of late years neither dredging nor repairs to the jetties have been needed, and the originally projected depth has been somewhat exceeded. Scour has now nearly ceased, the cost of maintenance has been practically nothing, and the dredges have been utilized at other harbors.

To provide greater depth at Charleston it seems probable that simple dredging is all that is necessary, the principle being well established that jetties will maintain a greater depth than their unaided action will originally create. It is pleasant to the writer to read a paper which accords so closely with his own ideas.

Mr. Taylor. JOHN TAYLOR, ASSOC. M. AM. SOC. C. E. (by letter).—Mr. Ripley's interesting paper presumably includes within its scope the design as well as the construction of a stone jetty, as he suggests certain dimensions for the cross-section, etc. Further information as to the conditions and exposure under which such designs are used would increase the value of the paper to other engineers engaged on the design of structures of this class, and it is hoped that the author will kindly supply this.

It is to be presumed that he does not intend such steep slopes for use on the sea face under all circumstances, whether adverse or otherwise. The widths he states to be subject to variation to suit the exposure and other local conditions. The writer has personal knowledge of sites on which breakwaters of the rubble mound type have been constructed where, entirely apart from the question of width, such slopes on the sea face would be cut into and breaches would be made in the superstructure in a very short time if stone of only reasonable size and such as is generally available were used. The larger the blocks of stone the steeper, of course, will be the slope at which the rubble may be expected to stand. In some European ports in exposed sites, where very large concrete blocks are used as a wave breaker on the sea face of rubble mounds, they stand at a comparatively steep slope, say, $1:1\frac{1}{4}$. In others, where more moderately sized but still

Mr. Taylor.

large rubble stone, weighing 1 ton and upward, have been used for this purpose, the slopes have been dragged down between tides and to varying levels below low tide to final slopes as flat as 1 : 10. This, of course, depends on the exposure and the material used, and it appears to the writer to be extremely difficult to lay down any hard and fast rule.

A sea water-wave of a given height develops the same energy, and consequently the same destructive and erosive power, in any part of the world, but its effect depends on the manner in which that energy is expended, that is, whether or not it is in shallow water, and also on the contour of the artificial obstacle placed in its way, which may convert its normal motion into a particularly violent forward and vertical one. This introduces the question of the comparative value of vertical walls, battered walls, walls with a submerged talus, mounds with long gradual slopes approaching to the contour of a natural beach, or those with a medium slope of, say, 1 : 2, and their effects on waves and consequently on themselves. There are also the many freak designs, introducing berms, ramps, and even sections of ellipses or parabolas on the sea face. These are founded on some assumption of the designer and, on the face of them, are inapplicable in positions where there is any considerable tidal range, as they generally assume a nearly uniform water level as a starting point on which the theory is based. Undoubtedly, the nearer the form of the work approaches to the vertical in deep water the less is the wave energy expended in a destructive form against it. The trouble with a rubble mound is to maintain it with the steep slope after construction. With such a slope a wave does not have time to acquire a violent forward movement, but, against this, there is the natural tendency of the rubble under erosion to assume a lower angle of repose.

The word, jetty, is evidently applied by Mr. Ripley to the semi-breakwater-training walls for regulation and protection purposes at the entrances of river and lagoon harbors, such as have been built at numerous points on the United States coast line. They are generally placed approximately at right angles to the general coast line, and parallel to the channel center line. The inner and less exposed sections of these are often subject to only moderate seas running across sand flats. The outer ends are often much exposed, and here the chief trouble in their maintenance is found. Perhaps the author will state the degree of exposure and wave height which such a structure as he typifies would withstand successfully with moderate maintenance.

Such designs have undoubtedly been successful and economical under fairly moderate conditions. The writer does not think, however, that they would survive in the more exposed sites on the Atlantic and Pacific Coasts without heavy maintenance charges, unless wider cross-

Mr. Taylor. sections, very heavy material, and much flatter slopes were used on the sea face. In a paper by Morton L. Tower, M. Am. Soc. C. E.,* it is stated that:

"for 800 lin. ft. the outer end of the Coos Bay Jetty was built three times to 24 ft. above low water and beaten down at the extreme end to 20 ft. below low water, or only a few feet above the surrounding sand."

It is one thing to design such a structure with steep slopes, and another to keep it so for any length of time; for repairs often reach such proportions that many of these works can only be looked on as still under construction for long periods after they are nominally completed according to the design. The slopes require continual additions in order to replace dislodged blocks until a final permanent condition is attained. Of course, this does not apply in all cases, but in very many it has proved to be absolutely necessary. Exposure in a rubble mound, as affecting the life of the structure, is not necessarily defined or limited by the direction of the work relative to the direction of prevalent storms and the general shore line, as the scouring action of waves from occasional storms, striking the work, head on or at an acute angle, will sometimes draw down the rubble slope as effectively as would waves attacking the structure more nearly at right angles.

The secret of success in a breakwater with steep slopes, such as described by the author, is undoubtedly the proper protection of the core by an outer covering of very heavy blocks on the superstructure and slopes. The weak point, however, is generally the foundation toe of the slope blocks, which receives the thrust of the wedging of the blocks caused by the settlement of the supporting core, due to the dead weight and the consolidation by wave impact. The wedging effect is the source of strength in the superstructure in such a design, if the toe is made secure.

The writer has had experience in the construction of 9 000 lin. ft., and the maintenance of about as much more, of rubble mound breakwaters, at the Portland Naval Harbor in Great Britain, running out into water 60 ft. deep at low tide. The different parts of the work were exposed to varying heights of seas due to different relative exposures, and several cross-sections were adopted to meet these conditions. Waves wheeling from the open Atlantic, up to 25 ft. in height at a moderate estimate, were projected against the most exposed parts, and here the sea slopes were flattest, averaging about 1 : 6 from high tide down to about 20 ft. below low tide. Other less exposed portions were steeper, but none was steeper than 1 : $2\frac{1}{2}$, even in the most sheltered parts, where 15-ft. waves were felt. A short temporary section, having a slope of 1 : $1\frac{1}{4}$ on the sea face failed to stand at the latter site.

* *Transactions*, Am. Soc. C. E., Vol. LXXI, p. 354.

The upper part of the work and the slopes down to low tide were covered by heavy stone "pitching," about 3 ft. thick and up to 10 tons in weight. The material is limestone from the low-grade beds in the quarries, has a specific gravity of about 2.45, and is very tough and durable. Below low tide the slope was deposited at random from dumping barges. At low tide a heavy toe of large, loose rubble was placed in order to protect the lower end of the "pitching." In one part the superstructure, down to low tide, has a slope of 1:2 with a 6-ft. berm of loose rubble as a toe for the pitching, and with the rubble below this level down to the sea bed continued on a slope of 1:2½. With an exposure in this portion giving waves sometimes 20 ft. high, considerable trouble was caused by the loosening of the toe blocks at low tide by wave action and the squeezing out effect due to the wedging of the pitching by the settlement of the core. The only preventive was found to be the addition of large quantities of heavy rubble along the toe, and the flattening of the slope under water to about 1:4 down to about 20 ft. below low tide, so as to provide a solid support for the toe of the cap blocks. In certain cases, of course, sand will sometimes accumulate against the work after its construction in shallow water, and thus provide a natural protection for the toe, but in other cases it may be eroded from alongside the mound and weaken it. The berm at low tide may also in itself be a weakness at certain stages of the tide in a storm, as it tends to trip up waves approaching the work and make them strike the lower cap blocks a heavier blow, while the resultant suction and undertow on the wave recoil tend to remove the loose berm blocks and dislodge the capping. Mr. Taylor.

In such work it is very difficult—and the cost is almost prohibitive—to place successfully and permanently by hand under water a continuation of the cap blocks, down the slope, and the only alternative is a heavy toe of loose rubble, from low tide downward, placed at a stable slope, which will depend on the exposure of the site.

Does the design given by Mr. Ripley ever contemplate the continuation of the hand-laid blocks down the slope below water to the foundation level? In deep water this would place the toe beyond the reach of wave action. On a site which dries at low tide the placing of the lower blocks can generally be easily done.

The trouble with a faulty foundation toe is that the lower blocks will be loosened by wave action and will slide downward and fall out, thus allowing the joints between those higher up the slope to open out and deprive the cap blocks of unity of resistance and the support given to each other by the thrust due to wedging together under settlement. Soon—following the dictum "United we stand, divided we fall"—they are easily loosened and dislodged by the alternate hammer and suction of heavy seas. The open joints also allow the smaller core stones to be eroded, and then the cap blocks fall in and

Mr. Taylor. tilt out of position. This general disintegration, once properly started, progresses rapidly and satisfactory repairs are often very costly. Systematic inspection and repairs after storms, before the damage has had time to advance too far, will do much to avoid this, but it often happens that proper provision, in the way of maintenance, plant, and finances, is not made to permit of this. It is useless to expect a rubble breakwater in an exposed site to survive in good condition without making such provision, and this question of upkeep enters largely into that of the ultimate cost.

The writer has noted portions of structures of this type where the core had settled away from the capping and left it unsupported except by the adjacent blocks, on account of lack of provision for such settlement, and the hasty placing of the capping before the core had sufficient time to consolidate properly. This, of course, is a source of weakness. As regards settlement in such mounds, the writer took measurements of one of the rubble breakwaters previously mentioned at a point where it reached a total height of more than 65 ft. This work had been under construction for 6 years, the material being deposited rather irregularly along it during that period. After the placing of the capping, and during the 2 years following its completion, it settled at a decreasing speed as much as 15 in. At the end of that time, or 8 years after the placing of the first layers of rubble in the foundation, it was still settling at the rate of about 3 in. per annum. The sea bed was fairly solid, silty mud, overlying boulder clay, which is a very common sea bottom. In a strong current which causes erosion of the sea bed as the work progresses, the common-sense method is to lay a foundation layer of rubble well ahead of the work. This layer would not in itself cause erosion while being placed, and it would effectively prevent that caused by the increased velocity of the currents around the end of the superstructure as it advanced.

The grading of the material in the core by the use of rubble of varying sizes, so as to fill the voids and give greater dead weight per unit of cube, is a vital point in such sea work, and is of course desirable. Small stones in the outer layers, however, are only a source of weakness, as they are easily eroded by waves.

Some rubble breakwaters—in the light of after experience—have apparently been built unnecessarily wide at the water line and consequently also throughout the section. Some of the first ones built were badly damaged, and there was a tendency to run to extremes in the designs. Any section much greater than that necessary to absorb wave impact without allowing the inner slope to be forced out, is a waste of material, though, of course, it is advisable to provide a generous factor of safety. Too narrow a structure will be endangered by being overtopped by waves. If the top level is made too wide, however, the effect on the cost of the work can readily be seen, as

the slopes have to be built to take this width, and the cube is thus increased. What this width is, for a given exposure, only experience of works actually built can decide, and Mr. Ripley's paper indicates that this economical width has been to some extent arrived at definitely on works with which he has been connected, given certain known sea conditions. Mr. Taylor.

There are so many rather indefinite factors in the design and construction of such works that it is almost impossible to reduce the resulting data to an easily used formula, and it is a waste of energy to attempt to apply any complex theory. Some of these varying factors at different sites are the specific gravity and the available sizes of the stone, the exposure and frequency of heavy storms, the depth of water, and the tidal range. The designed slope of the cross-section itself will also affect materially the resultant wave action on the work. Although the tidal range at one place is a constant, the varying depths of water, the sea bed contours, and the location of portions of the work may necessitate variations in the cross-section. In northern countries, like Canada, ice may remove the rubble by ice shoves and by exercising a sort of glacial action, when it floats away. In work of this class there is certainly room for the use of that invaluable commodity, common sense, and an earnest study of the forces of Nature to an extent perhaps greater than in any other form of Civil Engineering construction.

Does Mr. Ripley propose any special strengthening of the seaward end of these jetties, so as to maintain them at a fixed length? In rubble mounds, the exact location of the seaward end is often rather indefinite. In jetties of the type which he describes, the annual cost of maintenance per unit of length would be of interest, if accompanied by some idea of the exposure at the site of the particular work referred to. The choice between the construction of the so-called vertical concrete or masonry type, for instance, and a rubble mound, generally hinges on the difference between the combined first cost and capitalized maintenance charges in both types. Some very cheap and successful examples of the rubble mound have been constructed. The writer has no prejudices in favor of either type, other than those justified by local conditions.

Morton L. Tower, M. Am. Soc. C. E. (by letter).—This paper is a concise statement of the functions and methods of construction of jetties as built at the present time. For extensive jetties or breakwaters, as for no other class of engineering works, the construction must needs be made to fit the many existing local conditions and circumstances. Mr. Tower.

The selection of the principal materials of construction itself is scarcely ever one of choice, being limited to one or two classes of

Mr. Tower. stone; and the cost of transportation is out of practical consideration for the requisite quantity of material from a distant site.

The side slopes given by Mr. Ripley, namely: "1 : $1\frac{1}{4}$ on the sea side and 1 : 1 on the channel side," seem to the writer to be too steep for general application. For elevations lower than 12 ft. below the plane of low water, a slope of $1\frac{1}{2}$ horizontal to 1 vertical can be depended on in almost any exposure; and between that elevation and extreme high water, where the structure is exposed to severe wave stroke, it is believed that a much flatter slope will be found essential unless monolithic or interlocked masonry is used.

If the wall is to be monolithic or interlocked, a nearly vertical side will be more advantageous than a slope, owing to the water or wave cushion formed against such exposures. Structures of the vertical-wall type are only adapted to locations where the approach of the waves is over water sufficiently deep to allow them to pass without being tripped by the bottom, and their nature changed from an oscillating movement to one of translation. For severe locations the writer does not believe the art of jetty or sea wall construction has yet reached such an established stage that the finished side slopes or the weight of individual units can be safely stated.

Another feature of the paper with which the writer does not agree is the method of construction recommended, that is, commencing at the sea end of the proposed work and building shoreward.

In the first place, in many locations, especially in northern waters, this is entirely impracticable. Jetties at estuaries are built over long shoals from 1 to 3 or 4 miles in width, measured from the gorge to deep water beyond the obstructing shoal or bar. If the material is to be deposited from barges, the plant cannot be handled in the breaking waves on or near the shoal over which the jetty is most economically built, except during a few days in the fall. If the material is to be deposited from a tramway, no form of trestle yet used for jetty building is sufficiently strong to withstand a winter season of storm waves without a protection of stone reaching practically to low water. Tramways of the finest and strongest wooden piles, with batter piles and ties of wire rope to anchors for lateral stability, have been tried and found wanting.

In the second place, it would not be desirable to construct a jetty from the sea end shoreward, for the following reasons: With but very few exceptions, the volume of water passing into a harbor is as great as that passing out, and the flood tides are as strong as the ebb current. A larger proportion of flood tide will enter a harbor over the shoal water than will pass out by the same route on the ebb current. There are many reasons why this is so, and a short period of observation at any harbor entrance will prove the fact. An examination of

the sand of the bar, beaches, and shoals inside the harbor for a considerable distance up stream will prove that the material has been subjected to severe wave action, and that it is very recently from the sea. Considering these facts, the writer believes that in general the greatest improvement at harbor entrances is created, not by scouring out the bar, the material of which naturally settles just beyond the active effect of the jetty current, but by protecting the channel from the inrushing, sand-loaded currents, along the beach. These currents are aided in disturbing and moving the sand by the breaking waves in the shoal water. The material on reaching the gorge is deposited, and is picked up by the ebb current and carried seaward until the force of the ebb is retarded by dissipation in the ocean on the bar. Mr. Tower.

Considering the foregoing phenomena, it is held that the shore end of the jetties should be constructed first, and that they should be made tight and of ample height to prevent water-borne sand from being washed over the crest. That the scour to be encountered at the end of the work will add to the expense, is well understood, but for coasts of severe exposure there does not seem to be any practical way of lessening it at the present time.

It is expedient, of course, to construct quickly a length of tramway which can be protected with one season's work, and to provide a protecting mattress or apron over the entire distance, which can be built in a season.

However, perhaps all the foregoing points may be termed details, and these must be studied and the methods to be applied determined for each particular location.

Howard J. Cole, M. Am. Soc. C. E. (by letter).—In view of the fact that the completion of the Panama Canal will encourage the improvement of the harbors on the Pacific Coast, Mr. Ripley's paper is very timely. In fact, Chili has already taken the initiative, and has appointed a Harbor Improvement Commission which is now constructing under contract an extensive navy yard, dry dock, breakwater, and other harbor works at Talcahuano. A contract for the harbor works at San Antonio has recently been awarded, and bids for the construction of the harbor improvements at Valparaiso are now being received. Mr. Cole

Similar works are in contemplation for the ports of Arica, Iquique, Antofagasta, and Valdivia. Most of these ports will have rubble breakwaters of heavy cross-section, topped with massive concrete blocks, and will be in waters 50 ft. or more in depth.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WALTER HERBERT SEARS, M. Am. Soc. C. E.*

DIED OCTOBER 7TH, 1911.

Walter Herbert Sears, the son of Thomas B. and Louisa H. (Churchill) Sears, was born in Plymouth, Mass., on December 8th, 1847. He was graduated from the Massachusetts Institute of Technology in 1868.

He spent the remainder of 1868 and the following year at work on Prospect Park, Brooklyn, N. Y. In 1870 and 1871 he was employed in the office of Mr. John B. Henck, a Civil Engineer of Boston, Mass. From 1872 to 1874, Mr. Sears was engaged, as Chief Engineer, on the construction of water-works for Winchester, Mass., and from 1875 to 1879 he held a similar position at Pawtucket, R. I., where he had charge of the preliminary surveys and construction of the water-works.

In 1880-1881, as Chief Engineer, he constructed a water-works system for Stillwater, Minn., and, in 1882-1883, an extension of the water-works system of Winchester, Mass. In 1883-1884 he was an Assistant Engineer of the American Bell Telephone Company, in charge of placing underground wires in the vicinity of Boston, Mass., and Washington, D. C. As Resident Engineer, he constructed, in 1885-1887, a new water supply for Beverly, Mass., and the following four years were spent as Chief Assistant Engineer of the East Jersey Water Company, at Paterson, N. J.

In 1892 and 1893, Mr. Sears was Chief Assistant Engineer on the additional water supply for Rochester, N. Y. For the succeeding ten years, 1893 to 1903, he was engaged in general engineering practice, his work including the renewal of the water supply systems of Plymouth and Lincoln, Mass., and plans for a new water supply for Grand Rapids, Mich.

In 1903, Mr. Sears was engaged as a Department Engineer under the Commission on Additional Water Supply, appointed by Mayor Low to investigate the Catskill and other water projects for New York City, and was in charge of the Catskill Department. Following this engagement he was Resident Engineer for the Northern New Jersey Flood Commission, with offices at Paterson, N. J.

In 1904, Mr. Sears was appointed Division Engineer of the Croton River Division of the Aqueduct Commission of New York City, and had charge of the work in the vicinity of Katonah, N. Y. From August

* Memoir prepared by Emil Kuichling and Alfred Douglas Flinn, Members, Am. Soc. C. E.

1st, 1905, to January 9th, 1906, he was Acting Chief Engineer, and from the latter date to April 1st, 1910, Chief Engineer, in charge of the extensions of the Croton Water Supply. During this period the Cross River Reservoir was completed, and construction on the Croton Falls Reservoir was begun and carried nearly to completion. During the latter part of his engagement, Mr. Sears was taken ill and was unable to return to active work. He died at his home at Plymouth, Mass., on October 7th, 1911.

In 1897, Mr. Sears was married to Miss Ella M. Blackman of Plymouth, Mass., who, with three children, survives him.

Mr. Sears' professional work was marked by the great thoroughness with which he studied and treated every problem which came before him. He had the faculty of foreseeing physical difficulties, and when they presented themselves, he was ready with plans to surmount them. This preparedness was the result of his constant observation of the forces of Nature, whereby he became familiar with causes, effects, and processes which remain mysterious to less observant men. Little escaped his quick notice, either in active field operations or in quiet holiday rambles.

Such tastes soon developed in him a keen appreciation of the beauties of natural scenery, and when a Park Commission was created in Plymouth, about fifteen years ago, he was easily induced to become a member, remaining in office until his death. The formation of an attractive park system in his native city was a source of absorbing interest to him, and the beautiful results attained are largely due to the artistic plans which he, as a Commissioner, made without financial compensation. His unselfish civic interest was also displayed by presenting the city with an elaborate report on the improvement of its public water-works, and it is gratifying to note that his plans were duly carried out.

Although firm in his conclusions and duties, Mr. Sears was modest, gentle, and lovable in a high degree, and by these qualities he won the respect and sincere affection of many friends and associates who mourn his loss.

Mr. Sears was elected a Member of the American Society of Civil Engineers on October 5th, 1904.

WILLIS TUBBS TURNER, Assoc. M. Am. Soc. C. E.*

Died September 7th, 1911.

Willis Tubbs Turner was born at Vineland, N. J., on April 23d, 1869, and was educated at the Grammar and High Schools of that place. In 1891 he began his professional career, first, as Field

* Memoir prepared by William S. Post, Assoc. M. Am. Soc. C. E.

Assistant for the United States Geological Survey in the Sierra Nevadas, later, serving as Topographer, surveying and mapping various quadrangles in California and Washington, among which the San Antonio, Rock Creek, Tejon, Mt. Pinas, and Santa Ynez maps bear his name.

From 1896 to 1898 he was U. S. Surveyor in Indian Territory, in the subdivision and allotment of the Choctaw Nation lands. This was a rare instance in which the Government made its own land survey, with the interesting result that the cost was about two-thirds of that under the usual contract system, that all errors were corrected, corners were actually monumented, and, included in this cost and incidental to the work, was complete topographic mapping—a result due in great measure to the enthusiasm and sturdy perseverance of such young men as Mr. Turner. He remained on this duty in spite of malaria and typhoid fever, both of which he contracted at various times, but overcame with his robust constitution.

This experience and the mountain training acquired in the field work of the U. S. Geological Survey undoubtedly contributed greatly to his success; as an expert packer and a fine mountaineer, he could lead in exploration and organize his forces to the best advantage.

In June, 1903, Mr. Turner entered the U. S. Reclamation Service, and was in charge of surveys, reservoir sites, and canals on the Malheur, Harney, and Umatilla Projects, in Oregon; the early surveys of the Roosevelt Dam, in Arizona; of the border of Utah Lake and the Jordan River, in Utah; and had charge of the tests for hydraulic-fill dams and canals of the Sun River, in Montana.

In 1906, Mr. Turner was appointed Assistant Engineer of Montana, and was in charge of irrigation investigations, which included a report on the Cherry Creek Project.

In September, 1906, he accepted an offer of the Peruvian Government to take charge of its irrigation investigations, with the title of Chief of the Hydrographic Commission. In this new and important field, which included the whole subject of hydrography, duty of water, and hydro-electric development, he reported on the Lagunes Huarochiri, a series of some 65 lakes, with estimates for storage and plans for hydraulic-fill dams. These lakes are on the head-waters of the Rimac River, from which Lima derives its water supply. He also studied the Imperial Pampa, near the Canete River. During this period he was the author of the following publications: "Informas sobre el Rio Chillon," "Las Lagunas Huarochiri y Su Futuro Ensanche," and "Pantana Gallinaza y Su Desague."

Mr. Turner's correspondence at this time is of the greatest interest, the following being quoted in regard to one of his discoveries: "The most remarkable dam site I have ever seen is located some

twenty miles above Chosica on the Santa Eulalia River. The height is 460 feet, and 400 feet above stream bed has no greater width than 35 feet."

His letters also contain delightful comments on the methods and customs, which all engineers who have had to do with Central or South American matters, would keenly appreciate. In a characteristic and almost brusque judgment of methods, he refers to "the mania for reports" before facts are obtained.

Mr. Turner returned to the United States in May, 1910, and feeling that he needed a complete change, proposed to take up scientific farming for a year or two and then return to his Profession. He had purchased a farm and was so engaged when he contracted a severe cold which ultimately proved fatal. By the advice of his physician he went to New Mexico in hope of improvement, accompanied by Mrs. Turner. A complication of tubercular meningitis set in, however, and he died at Albuquerque, on September 7th, 1911. His wife and daughter, who frequently accompanied him on his many travels, and who were with him in South America, survive him.

Mr. Turner was a fine type of the Western engineer trained in the school of experience. He was uncompromisingly honest in all his relations and thoroughly understood himself. He was a good judge of human nature, positive, and forceful, and had a subtly humorous manner. Ambitious to excel in all that he undertook, his determination and constitution ensured its completion. His name is on the long list of those who have carried American engineering methods into far countries, and have paid the toll in health and with their lives.

Mr. Turner was elected an Associate Member of the American Society of Civil Engineers on December 7th, 1904.

JOSEPH HECKART FRAZER, Jun. Am. Soc. C. E.*

Died August 16th, 1911.

Joseph Heckart Frazer, the son of Eben B. Frazer, was born at Port Deposit, Md., on September 30th, 1882. He was graduated from Delaware College, Newark, Del., in 1903, with the degree of B. C. E. Immediately after his graduation, he entered the service of the Baltimore and Ohio Railroad Company, as Topographer, being engaged on engineering work in Maryland, Pennsylvania, and West Virginia, until November, 1904, when he resigned.

In January, 1905, Mr. Frazer began work with the Bolivian Railway Company, as Transitman on the preliminary surveys of the

* Memoir prepared by Mr. P. A. Seibert, Mgr., Andes Tin Company, La Paz, Bolivia.

Viacha-Oruro Line. He was also employed by the Bolivian Government as Engineer with the Commission for the Study of Railways.

In June, 1905, he was appointed Chief Engineer and Assistant Manager of the Concordia Mine, of the Andes Tin Company, being engaged in laying out and building roads and in the erection of an electrical transmission plant. In March, 1907, he resigned this position to form, with Mr. William R. Rumbold, of Tunbridge Wells, England, the firm of Rumbold and Frazer, with headquarters at Oruro, Bolivia. This firm made surveys and estimated costs for a wagon road across the Andes from Caluyo to Concordia Mine; reported on and estimated costs for a water supply for the City of Oruro; examined and reported on mining properties, etc.

In 1909, Mr. Frazer sold his interest in the firm of Rumbold and Frazer to Mr. A. Basil Reece, and became associated with Mr. Adam W. Yount, in the contracting and engineering firm of Yount and Frazer, at Oruro, Bolivia. This firm successfully completed contracts for the construction of important railways in Bolivia, among them being large portions of the lines from Rio Mulato to Potosi, and from Oruro to Cochabamba.

Mr. Frazer was one of the few Americans who have successfully managed large and important contracts with native labor, and, although a young man, had, by hard work and careful judgment, amassed a considerable fortune. He died of pneumonia, at La Paz, Bolivia, on August 16th, 1911, after an illness of seven days.

He was one of the most popular foreigners in Bolivia, a man of high ideals and lovable character, and leaves a record of clean, honest work.

Mr. Frazer was elected a Junior of the American Society of Civil Engineers on March 31st, 1908.

INDEX

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXVIII—No. 2

February, 1912

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXVIII—No. 2

FEBRUARY, 1912

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS

NEW YORK 1912

American Society of Civil Engineers

OFFICERS FOR 1912

President, JOHN A. OCKERSON

Vice-Presidents

Term expires January, 1913:	*Term expires January, 1914:*
ALFRED P. BOLLER	CHARLES S. CHURCHILL
CHARLES L. STROBEL	CHARLES D. MARX

Secretary, CHARLES WARREN HUNT

Treasurer, JOSEPH M. KNAP

Directors

Term expires January, 1913:	*Term expires January, 1914:*	*Term expires January, 1915:*
WILLIAM E. BELKNAP	GEORGE C. CLARKE	LINCOLN BUSH
HORACE LOOMIS	CHARLES W. STANIFORD	T. KENNARD THOMSON
GEORGE A. KIMBALL	JONATHAN P. SNOW	EMIL GERBER
PERCIVAL ROBERTS, JR.	ROBERT RIDGWAY	WILLIAM CAIN
CHARLES F. LOWETH	LEONARD W. RUNDLETT	E. C. LEWIS
ARTHUR DEWINT FOOTE	WILLIAM H. COURTENAY	W. A. CATTELL

Assistant Secretary, T. J. MCMINN

Standing Committees

(THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES)

On Finance:	*On Publications:*	*On Library:*
LINCOLN BUSH	WILLIAM E. BELKNAP	ALFRED P. BOLLER
HORACE LOOMIS	ROBERT RIDGWAY	CHARLES D. MARX
CHARLES W. STANIFORD	CHARLES S. CHURCHILL	EMIL GERBER
GEORGE A. KIMBALL	CHARLES L. STROBEL	CHARLES F. LOWETH
PERCIVAL ROBERTS, JR.	JONATHAN P. SNOW	CHAS. WARREN HUNT

Special Committees

ON CONCRETE AND REINFORCED CONCRETE: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

ON ENGINEERING EDUCATION: Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead.

ON STEEL COLUMNS AND STRUTS: Austin L. Bowman, Alfred P. Boller, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER..................5913 Columbus.
CABLE ADDRESS..................."Ceas, New York."

Vol. XXXVIII. FEBRUARY, 1912. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

FIFTY-NINTH ANNUAL MEETING*

January 17th, 1912.—The meeting was called to order at 10 A. M.; President Mordecai T. Endicott in the chair; Charles Warren Hunt, Secretary; and present, also, about 450 members.

Messrs. A. H. Van Cleve, L. E. Moore, H. H. Quimby, Henry S. Jacoby, H. N. Ogden, R. H. Brown, John G. Van Horne, C. W. Smith, R. V. Rose, and James Burden were appointed Tellers to canvass the Ballot for Officers for the ensuing year.

The Annual Report of the Board of Direction, and the Annual Reports of the Secretary and of the Treasurer,† for the year ending December 31st, 1911, were presented and accepted.

*A full report of the Fifty-ninth Annual Meeting is printed on pages 66 to 89 of this number of *Proceedings*.

†For these reports, see pages 13 to 22 of *Proceedings* for January, 1912 (Vol. XXXVIII).

The Secretary announced that the prizes for the year ending with the month of July, 1911, had been awarded by the Board of Direction, in accordance with the recommendations of the Committee to Recommend the Award of Prizes, as follows:

The Norman Medal to Paper No. 1165, "The New York Tunnel Extension of the Pennsylvania Railroad. Station Construction, Road, Track, Yard Equipment, Electric Traction, and Locomotives," by George Gibbs, M. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 1155, "The New York Tunnel Extension of the Pennsylvania Railroad. The North River Tunnels," by B. H. M. Hewett and W. L. Brown, Members, Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 1173, "A Concrete Water Tower," by A. Kempkey, Jr., Jun. Am. Soc. C. E.*

The Secretary presented the following resolution of the Board of Direction:

"*Whereas,* the expense of collations at the regular monthly meetings of the Society, which is less than $1 500 per annum, has heretofore been met by subscription among the resident members, and inasmuch as the regular dues of the resident members are 50% or more greater than those of non-resident members, and as the revenues of the Society are amply sufficient for all needs, the Board of Direction has thought it advisable in the future to pay for the collations from the Society funds.

"It is felt that the knowledge that these expenses are borne by voluntary subscriptions, may cause some of the younger resident members, who may not feel able to contribute substantially, to be diffident about attending the meetings, therefore, be it

"*Resolved,* That from this date the Treasurer be authorized to pay for the collations from the current funds of the Society."

On motion, duly seconded, the resolution was adopted.

Joseph R. Worcester, M. Am. Soc. C. E., Chairman of the Special Committee on Concrete and Reinforced Concrete, presented a Progress Report of that Committee.†

The report was accepted and the committee continued.

Desmond FitzGerald, Past-President, Am. Soc. C. E., Chairman of the Special Committee on Engineering Education, presented a Progress Report of that Committee.‡

The report was accepted and the committee continued.

The Secretary presented the Final Report of the Special Committee on Uniform Tests of Cement.§

The report was accepted and ordered printed.

---

* Now Assoc. M. Am. Soc. C. E.

† See page 69.

‡ See page 70.

§ See page 73.

Austin Lord Bowman, M. Am. Soc. C. E., Chairman of the Special Committee on Steel Columns and Struts, presented a Progress Report of that Committee.*

The report was accepted and the committee continued.

W. W. Crosby, M. Am. Soc. C. E., Chairman of the Special Committee on Bituminous Materials for Road Construction, presented a Progress Report of that Committee.†

The report was accepted and the committee continued.

The following were appointed members of the Nominating Committee to serve two years:

MERRITT H. SMITH.........	*Representing District No. 1*
HARRISON P. EDDY..........	" " " 2
A. E. KASTL...............	" " " 3
J. F. MURRAY..............	" " " 4
A. S. BALDWIN.............	" " " 5
J. F. COLEMAN.............	" " " 6
R. H. THOMSON.............	" " " 7

The Secretary read a communication from Percival M. Churchill, Assoc. M. Am. Soc. C. E., presenting the following resolution:

"*Resolved,* That the President appoint a Committee of eight members to look into the conditions of employment of Civil Engineers throughout the country, the compensation they receive, the duration of employment, the expenses for which they are re-imbursed by the employer, the expenses due to the work paid by the engineers themselves, the net yearly income, the prices charged for different classes of private work, and any other facts necessary to clearly set forth the problem. The report to set forth recommendations for action by the Society looking toward improving existing conditions and to include a report on the feasibility of this Society operating an employment bureau for its members covering all classes of engineering work. The Committee to consist of four employing engineers and four engineers holding subordinate positions. The Committee to be authorized to add to its membership and to fill vacancies. A preliminary report to be rendered in six months."

On motion, duly seconded, the resolution was referred to the Board of Direction.

H. M. Wilson, M. Am. Soc. C. E., moved that the Board of Direction be asked to consider a recurrence to the practice of having a lunch served at the Society House on the first day of the Annual Meeting.

The motion, being duly seconded, was carried.

The Secretary presented the report of the Tellers appointed to canvass the Ballot for Officers for the ensuing year.

---

*See page 73.

†See page 71.

The President announced the election of the following officers:

President, to serve one year:

John A. Ockerson, St. Louis, Mo.

Vice-Presidents, to serve two years:

Charles S. Churchill, Roanoke, Va.
Charles D. Marx, Stanford University, Cal.

Treasurer, to serve one year:

Joseph Moss Knap, New York City.

Directors, to serve three years:

Lincoln Bush, New York City.
T. Kennard Thomson, New York City.
Emil Gerber, Pittsburgh, Pa.
William Cain, Chapel Hill, N. C.
E. C. Lewis, Nashville, Tenn.
W. A. Cattell, San Francisco, Cal.

Mr. Macdonald and Mr. FitzGerald conducted Mr. Ockerson, the President-elect, to the chair.

Mr. Ockerson addressed the meeting briefly.

Adjourned.

SPECIAL MEETINGS FOR TOPICAL DISCUSSION ON ROAD CONSTRUCTION AND MAINTENANCE.

January 19th, 1912.—The first special meeting for topical discussion on "Road Construction and Maintenance" was called to order at 10.00 a. m.; President John A. Ockerson in the chair; Charles Warren Hunt, Secretary; and present, also, about 250 members and guests.

The Secretary announced that Arthur H. Blanchard, M. Am. Soc. C. E., would act as Secretary.

The discussion on the first topic, "Drainage and Foundations," was opened by James Owen, M. Am. Soc. C. E. The topic was discussed further by Messrs. Clifford Richardson, Franklin C. Pillsbury, Logan Waller Page, J. A. Johnston, Walter W. Crosby, Arthur H. Blanchard, Samuel Whinery, E. H. Thomes, H. P. Willis, Will P. Blair, and Edward N. Hines.

The second topic for discussion, "Fillers for Brick and Block Pavements," was opened by George W. Tillson, M. Am. Soc. C. E., who was followed by Messrs. E. A. Kingsley, Samuel Whinery, Will P. Blair, L. P. Sibley, Walter W. Crosby, D. E. McComb, Arthur H. Blanchard, H. B. Pullar, and William A. Howell.

Adjourned.

January 19th, 1912.—The second special meeting was called to order at 2.30 P. M.; James Owen, M. Am. Soc. C. E., in the chair; Arthur H. Blanchard acting as Secretary; and present, also, about 350 members and guests.

Arthur W. Dean, M. Am. Soc. C. E., introduced the third topic, "Bituminous Surfaces." The subject was discussed further by Messrs. Harold Parker, Philip P. Sharples, W. H. Fulweiler, William H. Connell, H. C. Poore, Arthur H. Blanchard, Fred E. Ellis, W. D. Uhler, Michael Driscoll, Clifford Richardson, Charles P. Price, Walter W. Crosby, J. W. Howard, James Kearney, J. A. Johnston, James Owen, R. A. MacGregor, A. S. Brainard, T. R. Bennett, A. N. Groves, G. Immediato, Henry B. Drowne, C. A. Kenyon, and J. S. Miller.

Adjourned.

January 20th, 1912.—The third special meeting was called to order at 10.00 A. M.; Walter W. Crosby, M. Am. Soc. C. E., in the chair; Arthur H. Blanchard acting as Secretary; and present, also, about 350 members and guests.

The opening discussion on the fourth topic, "Use of Bituminous Material by Penetration and Mixing Methods," prepared by Linn White, Esq., was read by the acting Secretary.

The topic was discussed by Messrs. Walter W. Crosby, H. B. Pullar, E. H. Thomes, Clifford Richardson, Arthur H. Blanchard, William H. Connell, Robert A. Meeker, Amos Schaeffer, J. A. Johnston, Franklin C. Pillsbury, A. F. Armstrong, E. M. Vail, J. W. Howard, Michael Driscoll, and Herbert Spencer.

Adjourned until 2.30 P. M.

January 20th, 1912.—A fourth special meeting was called to order at 2.30 P. M.; Walter W. Crosby, M. Am. Soc. C. E., in the chair; Arthur H. Blanchard acting as Secretary; and present, also, about 150 members and guests.

The discussion on the fourth topic was continued by Messrs. William H. Connell, Albert Sommer, R. B. Gage, R. S. Hutchison, F. Dunham, H. L. Collier, Walter W. Crosby, Arthur H. Blanchard, J. W. Howard, Herbert Spencer, T. H. Boorman, A. W. Dow, E. H. Thomes, Philip P. Sharples, Walter H. Fulweiler, Robert A. Meeker, and George W. Tillson.

Adjourned.

February 7th, 1912.—The meeting was called to order at 8.30 P. M.; Alfred Noble, Past-President, Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 168 members and 17 guests.

The minutes of the meetings of December 20th, 1911, and January 3d, 1912, were approved as printed in *Proceedings* for January, 1912.

A paper by Frederick C. Noble, M. Am. Soc. C. E., entitled "Notes on a Tunnel Survey," was presented by the author and illustrated with lantern slides. The subject was discussed orally by Messrs. George D. Snyder, B. F. Cresson, Jr., Robert Ridgway, S. M. Purdy, Lazarus White, and the author, Messrs. Snyder and Cresson illustrating their remarks with lantern slides.

The Secretary announced the election of the following candidates on February 6th, 1912:

As Members

Thomas Lacey Bonstow, Ciudad Camango, Chih., Mexico
Clarence Stanley Coe, Marathon, Fla.
John Leo Dickey, New Orleans, La.
Jasper Manlius Gibson, New York City
John Albert Johnston, Worcester, Mass.
Henry Isaac Oser, New York City
Harold Lionel Swindlehurst, Goulburn City, New South Wales, Australia

As Associate Members

Lawrence Brett, Wilson, N. C.
Theodore Stuart DeLay, Creston, Iowa
Ernest George Eagleson, Boise, Idaho
Reginald Guy Foster, Dallas, Tex.
William Francis, Havana, Cuba
Chester Arthur Garfield, West Shokan, N. Y.
Philip Holden Glover, Powell, Wyo.
Frank Caleb Kelton, Tucson, Ariz.
William Howard Koppelman, Louisville, Ky.
William Ainsworth McIntyre, Ardmore, Pa.
William Taft Newcomb, Philadelphia, Pa.
Guy Lynn Noble, Marathon, Fla.
George Addison Posey, San Francisco, Cal.
John Clinton Prior, Columbus, Ohio
William Everton Ramsey, Chicago, Ill.
Robert Stuart Royer, Roanoke, Va.
Edward Beniah Snell, New Haven, Conn.
Leigh E Stevens, Grand Rapids, Mich.
Robert Bruce Tinsley, Pedro Miguel, Canal Zone, Panama

Perry Topping, St. Louis, Mo.
Karl Eugene Vogel, Omaha, Nebr.
Walter Owen Washington, San Antonio, Tex.
George Edward Wells, Naugatuck, Conn.
Edbert Carson Wilson, Waterville, Me.
William Wilson, New York City

As Associates

Lewis Irving Fletcher, Estacada, Ore.
Prévost Hubbard, Washington, D. C.
Frank Price, Braddock, Pa.
Lucern S Stewart, Kansas City, Mo.

As Juniors

Santaro Arakawa, Stanford University, Cal.
Rogelio Lilo Capestany, Guayama, Porto Rico
Charles Edward Erickson, Seattle, Wash.
William Hawley Franklin, Seattle, Wash.
Mortimer Grunauer, New York City
George Alvin Hunt, San Francisco, Cal.
Lewis Thayer Kniskern, New York City
Simon Abraham Najjar, New York City
Frederick Ohrt, Porto Velho de San Antonio, Rio Madeira, Brazil
James Vernon Phillips, Waycross, Ga.
Maurice Roos Scharff, Birmingham, Ala.
Leo Westfall, Altamont, N. Y.

The Secretary announced the transfer of the following candidates on February 6th, 1912:

From Associate Member to Member

Jacob Herbst Brillhart, Bethlehem, Pa.
Leon DeVere Conkling, South Bethlehem, Pa.
William Albert Heindle, Wilmington, Del.
Tollef Bache Mönniche, Culebra, Canal Zone, Panama
John Castlereagh Parker, Rochester, N. Y.
Wilson Fitch Smith, Valhalla, N. Y.
Thomas Hollis Wiggin, New York City
George Wood, New York City

From Junior to Associate Member

Carroll Addison Biggs, Jackson, Mich.
Charles Ellsworth Haywood, New York City
Robert Leslie Holmes, Marshall, Tex.

Franklin Johnson Howes, Rochester, N. Y.
Harold Vincent Joslin, Pee Dee, N. C.
Clarence Adkins Neal, Kansas City, Mo.
Stephen Henley Noyes, Steelton, Pa.
Grover Cleveland Pruett, Miles City, Mont.
Louis John Sieling, Brooklyn, N. Y.
Walter James Spalding, Balboa, Canal Zone, Panama.

The Secretary announced the following deaths:

Frederick Wagoner Bennett, elected Member, October 7th, 1903; died January 8th, 1912.

William Billings Clapp, elected Member, December 6th, 1905; died December 26th, 1911.

Samuel Clarence Ellis, elected Member, August 7th, 1872; died January 21st, 1912.

Lewis Kingman, elected Member, July 1st, 1885; date of death unknown.

Henry Fiddeman Lofland, elected Member, June 2d, 1897; died January 14th, 1912.

Frank Otis Melcher, elected Member, March 3d, 1897; died January 22d, 1912.

Joseph Shuter Smith, elected Member, April 1st, 1874; died March 26th, 1907.

George Howard White, elected Member, May 2d, 1883; died December 29th, 1911.

Antonio Esteban Mesa, elected Associate Member, January 1st, 1896; died February, 1911.

Ulrich Taubenheim, elected Associate Member, February 1st, 1905; died December 19th, 1911.

B. N. Farren, elected Fellow, March 12th, 1870; died January 21st, 1912.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

January 17th, 1912.—The Board met, as required by the Constitution, at the House of the Society during the Annual Meeting, January 17th, 1912, at 1.20 P. M.; President Ockerson in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Belknap, Bush, Cain, Churchill, Clarke, Endicott, Knap, Loomis, Loweth, Macdonald, Ridgway, Staniford, and Thomson.

The first business in order was the election of a Secretary.

Mr. Hunt retired.

Chas. Warren Hunt was nominated for Secretary.

Nominations were closed.

It was resolved that a letter ballot be forwarded to each member of the Board, said ballot to be canvassed at the meeting of February 6th, 1912.

Mr. Hunt was recalled.

The following Standing Committees of the Board were appointed:

Finance Committee: Horace Loomis, George A. Kimball, Charles W. Staniford, Percival Roberts, Jr., Lincoln Bush.

Publication Committee: William E. Belknap, Robert Ridgway, Charles S. Churchill, Charles L. Strobel, Jonathan P. Snow.

Library Committee: Alfred P. Boller, Charles D. Marx, Emil Gerber, Charles F. Loweth, Chas. Warren Hunt.

Adjourned.

February 6th, 1912.—Vice-President Strobel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Belknap, Bensel, Bush, Churchill, Endicott, Gerber, Kimball, Loomis, Ridgway, Snow, Staniford, and Thomson.

Ballots for the election of a Secretary were canvassed, 27 being cast for Chas. Warren Hunt.

It was decided that the Annual Convention of the Society in 1912 shall be held at Saratoga, N. Y.

The resignations of 1 Member and 2 Juniors were accepted.

Ballots for membership were canvassed, resulting in the election of 7 Members, 25 Associate Members, 4 Associates, and 12 Juniors, and the transfer of 10 Juniors to the grade of Associate Member.

Eight Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

REPORT IN FULL OF THE FIFTY-NINTH ANNUAL MEETING, JANUARY 17TH AND 18TH, 1912.

Meeting called to order.

Wednesday, January 17th, 1912 (10 A. M.).—Mordecai T. Endicott, President, in the chair; Charles Warren Hunt, Secretary; and present, also, about 450 members.

THE PRESIDENT.—I call the Annual Meeting to order. There is a large ballot for officers to be canvassed to-day, and it will take a great deal of time, and for that reason the tellers will be appointed at once, so that they can begin their work. I appoint the following gentlemen as tellers to canvass the ballot for officers:

Tellers appointed.

A. H. Van Cleve,	R. H. Brown,
L. E. Moore,	John G. Van Horne,
H. H. Quimby,	C. W. Smith,
Henry S. Jacoby,	R. V. Rose,
H. N. Ogden,	James Burden.

Under the Constitution, the ballot does not close until 12 o'clock, noon, but as there are many ballots to count the canvass will go on while the meeting proceeds, and any members who have not voted and desire to do so, may vote at any time until noon to-day.

THE SECRETARY.—Mr. President, I desire to say to the tellers that the arrangements for canvassing the ballot have been made on the third floor, and the office force will assist them in cutting the envelopes, with the tally sheets, and in every other way. Everything has been arranged so that they may get through their work, if they are expeditious, in about an hour and a half.

THE PRESIDENT.—The report of the Board of Direction is next in order.

Report of the Board of Direction.

THE SECRETARY.—Mr. President, there are a number of copies of the Report of the Board of Direction here, and I think they ought to be distributed, and I will pass them around before I begin with the reading.

The Secretary read the Report of the Board of Direction.*

THE PRESIDENT.—What is your pleasure with respect to the report?

DESMOND FITZGERALD, PAST-PRESIDENT, AM. SOC. C. E.—I move that the report be received, accepted, and placed on file.

Motion duly seconded.

THE PRESIDENT.—Any remarks on the motion? It has been moved and seconded that the report be received, accepted, and placed on file. All those in favor of the motion please say "aye"; contrary, "no." Carried.

The report of the Secretary is next in order.

* See *Proceedings*, Am. Soc. C. E., Vol. XXXVIII, p. 13 (January, 1912).

The Secretary read his Report* of receipts and disbursements for the year, including a general balance sheet showing the financial condition of the Society.† Report of the Secretary.

The President.—What disposition will you make of the Secretary's report?

A Member.—I move, Mr. President, that it be received and placed on file.

The President.—It is moved and seconded that the Secretary's report be received and placed on file. Any remarks on the motion? Those in favor of the motion say "aye"; contrary, "no." Carried.

The report of the Treasurer is next in order.

Joseph M. Knap, Treasurer, Am. Soc. C. E.—Mr. President, this is simply a condensed form of the Secretary's report. Report of the Treasurer.

The Treasurer read his report.‡

That is all that is necessary to state here. It was brought out last year that the Society is putting away money, as the Secretary stated and as you can see here, and paying $10 000 a year on the bond and mortgage, which was the understanding when the mortgage was taken out, that it would be limited to $10 000 a year in the payment of this mortgage. We have also invested $20 000 in bonds which bring a little more interest than the 4% we have to pay the Equitable Life; all of which is respectfully submitted.

Motion made and seconded to accept the report.

The President.—It is moved and seconded that the report be accepted. Any remarks on the motion? All those in favor say "aye"; contrary, "no." It is carried.

The next item of interest is the award of prizes.

The Secretary.—Before reading that report I would like to make an announcement concerning the excursions this afternoon. W. N. Beach, Assoc. M. Am. Soc. C. E., extends an invitation to all who propose visiting the Fourth Avenue Subway work in Brooklyn, to lunch with him at the Hof Brau Haus, which is at 588 Rockwell Place, Brooklyn. A luncheon will be served at 1 p. m. That means, of course, if you get there. To get to this place you take the subway to Nevins Street Station, Brooklyn, which is right near it. Announcements.

The object of giving this luncheon at this time is to enable those who go there, those who want to see that subway work, to get together in a party; otherwise they would probably straggle around and get their lunches anywhere, and not arrive, or arrive so late that they could not be handled properly. All those who want to see this work had better take advantage of this opportunity.

Mr. President, in accordance with the recommendation of the Coun-

* See *Proceedings*, Am. Soc. C. E., Vol. XXXVIII, p. 20 (January, 1912).

† See *Proceedings*, Am. Soc. C. E., Vol. XXXVIII, p. 19 (January, 1912).

‡ See *Proceedings*, Am. Soc. C. E., Vol. XXXVIII, p. 22 (January, 1912).

Award of Prizes.

mittee appointed to Recommend the Award of Prizes for the year ending with the *Transactions* of July, 1911, the Board of Direction has awarded the prizes as follows:

The Norman Medal to Paper No. 1165, "The New York Tunnel Extension of the Pennsylvania Railroad. Station Construction, Road. Track, Yard Equipment, Electric Traction and Locomotives," by George Gibbs, M. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 1155, "The New York Tunnel Extension of the Pennsylvania Railroad. The North River Tunnels," by B. H. M. Hewett and W. L. Brown, Members, Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 1173, "A Concrete Water Tower," by A. Kempkey, Jr., Jun. Am. Soc. C. E.*

The tellers report, if I may say a word, that they are one short. There were ten tellers appointed, and they do not know exactly who it is that is absent. They know their own names, but they do not know who is missing. The tellers who were appointed were A. H. Van Cleve, L. E. Moore, H. H. Quimby, H. S. Jacoby, H. N. Ogden, R. H. Brown, John G. Van Horne, C. W. Smith, R. V. Rose and James Burden. If any one of these gentlemen is here and will proceed to the third floor, the tellers will be glad to see him.

Announcements.

Mr. Beach, who has invited the party to luncheon, has provided a card, which shows how to get to the Hof Brau Haus. These cards will be passed around so that the Hof Brau Haus may receive its expected guests.

I would like to make an announcement as to one of the other excursions for this afternoon. George A. Harwood, M. Am. Soc. C. E., Chief Engineer of Electric Zone Improvements of the New York Central Railroad, says that he would appreciate it if members who intend to visit the terminal this afternoon would assemble promptly between 2.15 and 2.30 o'clock, as will be noted from the programme. It will otherwise be difficult to make the round before dark.

This programme, which Mr. Harwood has taken a great deal of trouble to work out, states that the party is to assemble at 2.15 P. M., at the Concourse, at Lexington Avenue Temporary Terminal, street level, opposite 44th Street. They will proceed to the suburban level at 2.30 P. M., so that the place to meet, for those who wish to see the New York Central work, is at the Concourse at Lexington Avenue, opposite 44th Street, at the street level, at 2.15 P. M.

Resolution in regard to Collations.

THE PRESIDENT.—There is a resolution of the Board of Direction in regard to the payment for collations at the regular meetings of the Society. I shall ask the Secretary to present it.

THE SECRETARY.—"*Whereas,* the expense of collations at the regular monthly meetings of the Society, which is less than $1 500 per annum,

*Mr. Kempkey has since become an Associate Member.

has heretofore been met by subscription among the resident members, and inasmuch as the regular dues of the resident members are 50% or more greater than those of non-resident members, and as the revenues of the Society are amply sufficient for all needs, the Board of Direction has thought it advisable in the future to pay for the collations from the Society funds.

"It is felt that the knowledge that these expenses are borne by voluntary subscription may cause some of the younger resident members, who may not feel able to contribute substantially, to be diffident about attending the meetings, therefore, be it

"*Resolved:* That from this date the Treasurer be authorized to pay for the collations from the current funds of the Society."

That is a resolution which the Board offers to this meeting for consideration.

The President.—Gentlemen, you have heard the resolution. Any remarks upon it?

S. Whinery, M. Am. Soc. C. E.—I move that the resolution be adopted.

Motion duly seconded.

The President.—It is moved and seconded that the resolution be adopted. Any remarks on the motion? All in favor of its adoption will say "aye"—it is a unanimous vote, I guess—contrary, "no." It is adopted.

Report of Committee on Concrete and Reinforced Concrete.

There are a number of reports of Special Committees before the Meeting. The first is that of the Special Committee on Concrete and Reinforced Concrete, J. R. Worcester, M. Am. Soc. C. E., Chairman.

Mr. Worcester presented the following report:

PROGRESS REPORT OF THE SPECIAL COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

The Special Committee on Concrete and Reinforced Concrete has met five times during the year: four times in New York City, and once at Atlantic City.

At the first three meetings, the Committee gave careful consideration to criticisms of its first Progress Report, presented to the Society in January, 1909, and reviewed the substance of the Report in detail, making corrections and modifications. At the fourth meeting of the Committee, at Atlantic City, the result of its previous study was presented in print, and the representatives of the American Society for Testing Materials, the American Railway Engineering Association, and the Association of American Portland Cement Manufacturers, constituting with the Special Committee the Joint Committee previously organized, were invited to attend and to consider the proposed revisions and modifications.

At this meeting the entire report was reconsidered, and parts deemed

Report of Committee on Concrete and Reinforced Concrete (continued).

susceptible of further improvement were referred to Special Sub-Committees. It was then hoped that it would be possible to complete the labors of the Committee in season to present to the Society at this time a revised draft covering the entire subject. Owing to unforeseen difficulties, however, the Committee is disappointed in this hope, and is obliged to ask the indulgence of the Society to the extent of granting further time.

Respectfully submitted, on behalf of the Committee,

J. R. WORCESTER,
Chairman.
RICHARD L. HUMPHREY,
Secretary.

H. M. WILSON, M. AM. SOC. C. E.—Is it in order at this time to speak?

THE PRESIDENT.—Yes.

MR. WILSON.—The motion just passed concerning the payment for the customary refreshments out of the Society funds interested me greatly, and I am sure every one here was glad to vote for it. May I ask, in that connection, what has become of one of the principal social functions of the Annual Meeting, the noon luncheon? Why ought that not to be resumed out of the funds of the Society? I would like to offer for the purpose of debate a motion to that effect.

THE PRESIDENT.—That will be in order at a later time. When you arose I thought you were going to address yourself to the Committee's report. That can be done later. Gentlemen, you have heard the report of the Special Committee on Concrete and Reinforced Concrete.

MR. FITZGERALD.—I move that the report be accepted and the committee continued.

Motion duly seconded.

THE PRESIDENT.—Gentlemen, you have heard the motion. Any remarks on the motion? All in favor say "aye"; contrary, "no." Carried.

Report of Committee on Engineering Education.

The next report is by the Special Committee on Engineering Education, Past-President Desmond FitzGerald, Chairman.

Mr. FitzGerald read the following report:

REPORT OF THE SPECIAL COMMITTEE ON ENGINEERING EDUCATION.

BROOKLINE, MASS., 16th Jan., 1912.

To the American Society of Civil Engineers:

The Committee on Engineering Education submits the following report:

During the past year investigations have been continued of the work of instruction as carried on by twenty of the leading technical schools and colleges in the United States.

In order to obtain a clearer idea of the hours of work devoted to different studies, including hours of preparation, a new blank was prepared covering the Course of Civil Engineering.

On the left side of the sheet, the studies were all divided into 8 groups: Mathematics, Physics and Chemistry, Humanistic, Drawing, Shop-work, General Engineering, Allied Sciences, and Civil Engineering. These groups were further divided into subsidiary groups and studies; for instance, under Civil Engineering, there were, Surveying, Structures, Railroads, Hydraulics, and Municipal Engineering. In all of the groups there were 102 studies.

Vertically, the sheets were divided into "Hours in Outside Preparation, Hours in Laboratory, Hours in Class Room, Hours of Instruction by Formal Lectures, and Hours in Summer Work."

It was hoped by the larger Committee with which your Committee have been acting, that these statistics, when gathered and analyzed, would give a fair idea of the work of instruction in the different institutions.

Much time was consumed in the effort to have these blanks filled out correctly; as a general rule, the schools aided to the best of their ability, although in some cases at the sacrifice of valuable time both in collation and correspondence.

These statistics were analyzed by the Chairman during the past summer and profiles plotted of the results; finally at an important meeting held recently in New York the results were carefully discussed.

This meeting was attended by representatives of the schools and by those who believe that the present methods of instruction are not in the right direction.

Different views of Engineering Education were unfolded, and reforms advocated and dissected.

As a result of the work, your Committee takes pleasure in reporting that there is every prospect that the whole matter of Engineering Education will be taken up in a scientific manner by the Carnegie Foundation, which recently did the same thing for Medical Education, in which they expended $40 000, with grand results—rendering an inestimable benefit to that branch of scientific instruction.

Your Committee feels secure in expressing the belief that in this happy result of concerted action we have been able to accomplish for this Society, its share of successful labor.

Respectfully submitted,

Desmond FitzGerald,
Chairman.

B. M. Harrod,
Onward Bates.

Report of Committee on Engineering Education (continued).

Mr. FitzGerald.—Finally, I have here a form of the final blank, which was adopted by this committee, as already described, if anybody wishes to see it, and also I have here one of the profiles, in which the results of these studies in all the different schools were plotted. These statistics were analyzed, as I have stated, and finally, at an important meeting held recently in New York, the results were carefully discussed.

This meeting was attended by representatives of the schools, and by those who believe that the present methods of education are not in the right direction. Different views of engineering education were unfolded, and reforms advocated and discussed. As a result of the work your Committee takes pleasure in reporting that there is every prospect that the whole matter of engineering education will be taken up in an exhaustive manner by the Carnegie Foundation, which recently did the same thing for medical education, in which they expended $40 000, with grand results, rendering an inestimable benefit to that branch of scientific instruction.

I hope some of you gentlemen know something of the details of that work, and of the wonderful results that have come from it. It may not be possible that the same wonderful results will come from the matter of engineering education, but if the Carnegie Foundation are willing to take it up in the same way that they have medical education, nothing could be better.

The President.—You have heard the report, gentlemen. What disposition do you wish made of it?

Mr. Whinery.—I move that the report be accepted and the Committee continued.

Motion duly seconded.

The President.—It is moved and seconded that the report be accepted and the committee continued. Any remarks on that motion? Those in favor will say "aye"; contrary, "no." It is carried.

Report of Committee on Uniform Tests of Cement.

The next report that we have is by the Special Committee on Uniform Tests of Cement, a final report, by George S. Webster, Chairman.

George S. Webster, M. Am. Soc. C. E.—The Secretary has the report, if he will read it.

The Secretary read the report:*

The President.—Gentlemen, this is presented as a final report. What will you do with it?

A Member.—I move that the report be received and printed.

Motion duly seconded.

The President.—It is moved and seconded that the report be received and printed. Are there any remarks on that motion? Those in favor will say "aye"; contrary, "no." Carried.

* See p. 103.

During the reading of the other papers I hope that the gentlemen assembled near the door will refrain from conversing, as far as possible. Sometimes the sound carries over here and interferes with the reading.

C. McD. Townsend, M. Am. Soc. C. E.—Mr. President, I would like to make a little supplementary remark for the Army Board, of which I was a member and which disagreed with these gentlemen. I desire to state that four of the members of this Army Board are members of the American Society of Civil Engineers, and one a member of this Committee. It was with great regret that we were unable to agree with this Committee; but we felt that we were really recommending the actual practice of the majority of the members of the American Society when we adopted our report.

The President.—The next report is by the Special Committee on Steel Columns and Struts, by A. L. Bowman, M. Am. Soc. C. E., Chairman. Report of Committee on Columns and Struts.

Mr. Bowman presented the following report:

PROGRESS REPORT OF THE SPECIAL COMMITTEE ON STEEL COLUMNS AND STRUTS.

The Special Committee, "to consider and report upon the design, ultimate strength, and safe working values of Steel Columns and Struts," presents the following report of progress:

Your Committee, during the past year, has devoted its attention to the study of the records of tests which have been available, including those recently made by Mr. Jas. E. Howard, and published in *Transactions,* Vol. LXXIII. The relation between ultimate failure and yield point, or elastic limit, as shown in the records of full-sized tests, has been studied to determine the influence of these two very important factors.

The details in connection with the proposed series of tests to determine the influence of shape of columns on the strength has occupied a considerable amount of your Committee's time. With the co-operation of the Bureau of Standards of the United States Government, S. W. Stratton, Director, your Committee has secured prices for this special work. These columns will be the first tested on the new testing machine now being installed at Washington, D. C., and the Government expects to begin work on the programme this fall.

The Committee on Iron and Steel Structures of the American Railway Engineering Association has been instructed by their Board of Direction to report on the design of large columns, and the Chairman of this Committee, Mr. C. H. Cartlidge, has communicated with your Committee, with a view of acting in harmony to avoid duplication of the work.

Report of Committee on Columns and Struts (continued).

Until your Committee can secure the results of the proposed programme of tests, it is not in a position to make a final report.

For the Committee:

AUSTIN LORD BOWMAN, *Chairman.*
LEWIS D. RIGHTS, *Secretary.*

Committee:

A. P. BOLLER,
AUSTIN LORD BOWMAN,
EMIL GERBER,
CHAS. F. LOWETH,
RALPH MODJESKI,
FRANK C. OSBORN,
GEO. H. PEGRAM,
LEWIS D. RIGHTS,
GEO. F. SWAIN,
EMIL SWENSSON,
J. R. WORCESTER.

THE PRESIDENT.—What is your pleasure, gentlemen, in regard to the report?

A MEMBER.—Mr. President, I move that the report be received and filed.

Motion duly seconded.

THE PRESIDENT.—It is moved and seconded that the report be received and filed, and that the committee be continued. Those in favor of the motion say "aye"; contrary, "no." Carried.

Report of Committee on Bituminous Materials for Road Construction.

The next report to be presented is that of the Special Committee on Bituminous Materials for Road Construction, by W. W. Crosby, M. Am. Soc. C. E., Chairman.

Mr. Crosby presented the following report:

PROGRESS REPORT OF SPECIAL COMMITTEE ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION.

To the American Society of Civil Engineers.

GENTLEMEN:

Your Special Committee on "Bituminous Materials for Road Construction" respectfully submits the following Progress Report:

Your Committee believes that, in order to solve many of the problems of construction and maintenance, it is more necessary to have at hand physical data recorded along uniform lines for a relatively short period than to prove the correctness of certain fine theoretical points. Your Committee, therefore, regrets an apparent tendency in some instances to ignore the opportunity offered by the Committee for collaboration, which would result in mutual benefit.

and deprecates any tendency to return to the former chaotic conditions which would ensue from individual, non-concurrent effort.

Your Committee submits, under the following heads, recommendations relative to the use of Bituminous Materials in the Construction and Maintenance of Roads:

1.—Traffic Census.—Your Committee desires to emphasize the fact that experience has demonstrated the value of traffic censuses taken both preliminary and subsequent to the construction of a highway.

The traffic census should be considered one of the most important variable factors in the solution of that important problem, the selection of that type of road or pavement best suited to local conditions considered from both the standpoints of economy and efficiency. In connection with the census returns on any road should be considered the traffic on cross and parallel highways and the effect of improvement of these highways on the traffic of the highway under consideration.

It should not be taken for granted that the bald return of a traffic census should be the sole basis of the selection of the type of road or pavement, but it should be considered a guide in estimating the value of the type of construction adopted.

The form for a traffic census proposed by your Committee has proved satisfactory, and its future use is recommended.

2.—Crown.—The investigations and observations of the Committee to date have convinced it that the crown generally used in the construction of macadam roads is excessive when bituminous materials are used, and that a crown of even ½ in. to the foot should be avoided when a lesser crown can be secured without detriment to the surface drainage.

3.—Sub-Grades and Foundations.—Your Committee believes that the use of any form of a bituminous surface does not preclude the necessity for the construction of a well-drained, thoroughly compacted, and adequate sub-grade. In fact, such improvement of the road surface frequently attracts heavier traffic, and thus increases the stresses in the sub-grade.

4.—Bituminous Materials.—Your Committee feels it is as yet too early to report specific details as to the characteristics, desirable or undesirable, of such materials.

Your Committee recommends, however, that especial attention be directed during the coming year to the following:

a.—The maximum amount of distillate from tars coming over, up to 170° cent., as determined by the test proposed by your Committee, that can be satisfactorily allowed;

b.—The maximum percentage of free carbon that can be suc-

Report of Committee on Bituminous Materials for Road Construction (continued).

cessfully allowed in a tar used for superficial treatment under varying climatic conditions;

c.—The maximum amount of residue and the limitations of penetration thereof that can be satisfactorily permitted in an asphaltic oil used for superficial treatment when such residue is obtained and tested under the evaporation test proposed by your Committee for such materials at 170° cent.

5.—Methods of Construction:

(*a*) Your Committee wishes to emphasize the fact that the selection of the method of construction to be used in a given case will depend upon the results of preliminary investigations, and that the recent and imminent development of mechanical appliances will affect the decision to a great degree.

(*b*) Your Committee is of the opinion that, whatever method may be used in any case, it is essential, as in water-bound macadam construction, that a suitable quality of road metal be used.

(*c*) Your Committee is of the opinion that, whatever method of construction is selected, the use of a bituminous material by no means justifies any lack of care in the ordinary details to be followed, but rather increases the need for thoroughness and skilled supervision.

6.—Construction Details.—Your Committee recommends:

(*a*) That trap rock in sizes greater than that passing a 2-in. screen should be used with caution in the construction of the upper course, unless the voids of the same are properly reduced, because of the liability of the individual stones to rock under traffic.

(*b*) That in the use of a heated aggregate for the construction of a bituminous pavement, non-uniformity or excess in the heating of stone, such as usually occurs with the use of flat plates or similar crude appliances for this purpose, should be avoided.

(*c*) The consideration of the use of a seal coat on bituminous pavements constructed by the mixing method, and which are subjected to a traffic of more than 10 horse-drawn commercial vehicles per day per foot of width of metalled surface.

7.—Cost Data.—In the work of the Committee, it has become apparent that conclusions may necessitate the use of cost data, recorded along uniform lines. It seems urgent that standards for arriving at costs be established and generally adopted as promptly as possible. Your Committee, therefore, recommends to the attention of the Profession this important feature of engineering work, with the hope that uniform methods will be generally adopted at an early date for reporting Costs of Construction, such as those proposed by this Committee in its Report Forms.

8.—Nomenclature:

(*a*) Your Committee wishes to advise strongly the discontinuance of the use of the terms "liquid asphalt" and "asphaltic contents,"

since these terms are meaningless in many cases, and unnecessary when proper tests, such as are recommended by your Committee, are used.

(*b*) For the sake of convenience and uniformity, your Committee advocates the adoption of the following definitions covering the present ordinary use of bituminous materials in road construction:

"Bituminous Surfaces" consist of superficial coats of bituminous materials with or without the addition of stone or slag chips, gravel, sand, or material of similar character.

"Bituminous Pavements" are those composed of stone, gravel, sand, shell, or slag, or combinations thereof, and bituminous materials incorporated together.

Very respectfully,
W. W. Crosby, *Chairman,*
Hubert K. Bishop,
Arthur W. Dean,
Arthur H. Blanchard, *Secretary.*

The President.—Gentlemen, what will we do with the report?

A Member.—Mr. President, I move that the report be accepted and printed.

Motion duly seconded.

The President.—It is moved and seconded that the report be accepted and printed. Any remarks on the motion? Those in favor say "aye"; contrary, "no." Carried.

The Secretary.—If I may interrupt this proceeding for just a moment: the tellers ask for a ruling on certain ballots. There is one place where there are two nominees for one office; in another place there are three nominees for two offices. If a man sends in a ballot with no scratch mark on it, the tellers would like to know whether that ballot is entirely invalidated, or whether it can be counted, and should be counted, for all the other candidates for which the gentleman is supposed to be voting in the other districts. They wish to know whether something which is improper in one particular district invalidates the whole ballot or not.

The President.—That is for the meeting to decide. I presume you all understand it.

The Secretary.—I think the Chair ought to rule.

The President.—What is your pleasure?

Foster Crowell, M. Am. Soc. C. E.—I move that the Chair rule on the matter.

Motion duly seconded.

The President.—The Chair will rule that it will invalidate only the vote for the particular office in question: that all others are regular.

Do you want the Nominating Committee next, Mr. Secretary?

Announcements.

THE SECRETARY.—There are so many more people in the room now that, before taking up that report, I would like to repeat the announcements that I made before in the meeting. With reference to the Grand Central Station, those who wish to see that work should, at the request of Mr. Harwood, meet promptly at 2.15 at the Concourse on Lexington Avenue Temporary Terminal at the street level opposite 44th Street. Mr. Harwood says that unless you start at that time it will be difficult to see all the work before dark.

The other announcement was with reference to the Fourth Avenue Subway work in Brooklyn. W. N. Beach, Assoc. M. Am. Soc. C. E., has invited those members who wish to see this work to lunch with him at the Hof Brau Haus, which is at 588 Rockwell Place, Brooklyn, between Fulton Street and Flatbush Avenue, and to get there you take a subway train to the Nevins Street Station, Brooklyn, and refer to the sketch on the card which has been distributed; those who want a copy can get it here.

Nominating Committee.

THE PRESIDENT.—The Report of the Nominating Committee.

THE SECRETARY.—Mr. President, I beg to report that the final suggestions received for members of the Nominating Committee to be appointed from the several districts are as follows:

District No. 1: Total number of suggestions received, 295, as follows:

MERRITT H. SMITH	180
S. H. WOODARD	73
GEORGE A. HARWOOD	36
RUDOLPH P. MILLER	2
GEORGE T. HAMMOND	1
GEORGE E. LOW	1
T. KENNARD THOMSON	1
W. J. WILGUS	1

THE PRESIDENT.—Gentlemen, you have heard the report with respect to the First District. I am informed that it is the custom to take up each district separately and act upon it. You have heard the suggestions, what is your pleasure?

A MEMBER.—I move that Merritt H. Smith be declared member of the Nominating Committee from District No. 1.

Motion duly seconded.

THE PRESIDENT.—It is moved and seconded that Merritt H. Smith be declared the nominee from the First District. Any other motion? Those in favor of that will say "aye"; contrary, "no." Carried.

THE SECRETARY.—District No. 2: Total number of suggestions received, 185, as follows:

H. P. EDDY	69
J. R. WORCESTER	51
S. E. TINKHAM	41

J. W. Rollins, Jr.	20
H. A. Carson	1
John E. Hill	1
John Kennedy	1
T. H. McKenzie	1

A Member.—I move that Harrison P. Eddy be appointed a member representing the Second District.

Motion duly seconded.

The President.—It is moved and seconded that Harrison P. Eddy be made a member of the Nominating Committee from the Second District. Those in favor of the motion say "aye"; contrary, "no." Carried.

The Secretary.—District No. 3: The total number of suggestions received, 233, as follows:

A. E. Kastl	88
Gardner S. Williams	32
W. L. Darling	30
E. E. Haskell	26
F. E. Crane	13
E. B. Guthrie	13
S. T. M. B. Kielland	13
William B. Patton	8
G. A. Ricker	7
Louis H. Knapp	1
L. C. Sabin	1
W. J. Sando	1

The President.—What is your action with respect to District No. 3?

Gardner S. Williams, M. Am. Soc. C. E.—I move that A. E. Kastl be declared a member of the Nominating Committee from District No. 3.

Motion duly seconded.

The President.—It is moved and seconded that Mr. A. E. Kastl be appointed a member of the Nominating Committee from District No. 3. Those in favor of the motion say "aye"; contrary, "no." Carried.

The Secretary.—District No. 4: Total number of suggestions received, 220, as follows:

J. F. Murray	93
J. E. Greiner	63
E. K. Morse	61
W. C. Furber	1
Frank P. McKibben	1
Logan W. Page	1

Nominating Committee (continued).

A MEMBER.—I move that J. F. Murray be declared the member of the Nominating Committee for the Fourth District.

Motion duly seconded.

THE PRESIDENT.—It is moved and seconded that J. F. Murray be declared a member of the Nominating Committee from District No. 4. All those in favor of the motion say "aye"; contrary, "no." Carried.

THE SECRETARY.—District No. 5: Total number of suggestions received, 202, as follows:

A. S. BALDWIN	92
J. V. HANNA	48
W. G. RAYMOND	25
C. A. MORSE	19
G. W. CRAIG	14
WILLIAM M. HUGHES	1
E. C. SHANKLAND	1
A. N. TALBOT	1
J. A. L. WADDELL	1

THE PRESIDENT.—What is your action on these suggestions?

A MEMBER.—I move that A. S. Baldwin be declared a representative of the Fifth District on the Nominating Committee.

Motion duly seconded.

THE PRESIDENT.—It is moved and seconded that A. S. Baldwin be declared a member of the Nominating Committee from the Fifth District. Those in favor of the motion say "aye"; contrary, "no." Carried.

THE SECRETARY.—The Sixth District: Total number of suggestions received, 151, as follows:

J. F. COLEMAN	63
F. M. KERR	45
F. L. NICHOLSON	39
L. C. HILL	2
W. H. CALDWELL	1
B. M. HALL	1

THE PRESIDENT.—What is your action on these suggestions?

A MEMBER.—I move that J. F. Coleman be appointed on the Nominating Committee from the Sixth District.

Motion duly seconded.

THE PRESIDENT.—Gentlemen, you have heard the motion. Those in favor of it will say "aye"; contrary, "no." Carried.

THE SECRETARY.—District No. 7: Total number of suggestions received, 251, as follows:

R. H. THOMSON	113
G. G. ANDERSON	65
H. N. SAVAGE	53

C. W. Comstock	10
H. W. Cowan	1
E. Duryea, Jr.	1
J. D. Galloway	1
Allen Hazen	1
D. C. Henny	1
E. B. Hussey	1
Joseph Jacobs	1
E. F. Haas	1
A. R. Livingston	1
C. S. MacCalla	1

Mr. Hazen is not eligible because he does not live in District No. 7.

The President.—The Chair will entertain a motion in regard to the election of a member of the Nominating Committee from the Seventh District.

A Member.—I move that R. H. Thomson be appointed to represent the Seventh District on the Nominating Committee.

Motion duly seconded.

The President.—All those in favor of the motion say "aye"; contrary, "no." Carried.

The next thing to be presented to you is a letter from Percival M. Churchill, Assoc. M. Am. Soc. C. E., suggesting the appointment of a committee to look into the subject of the employment of Civil Engineers, etc.

Resolution Regarding Appointment of Committee on Compensation of Engineers.

The Secretary.—Mr. Churchill is an Associate Member of the Society. He writes under date of January 8th to the Secretary, as follows:

"Elmwood, Mass., Jan. 8, 1912.

"*The Secretary, Am. Soc. C. E.,*

"220 West Fifty-seventh St., New York City.

"Dear Sir:—The question of compensation for engineers has been under discussion a great deal during recent years, but has not yet crystallized into action. Propositions for various forms of unions have been generally frowned upon as tending to lower the dignity of the profession, while other suggested lines of action seem only applicable locally. The blame for existing conditions has been variously assigned to the shoulders of the public, the employing engineer, demand and supply, lack of initiative on the part of the engineers themselves, and to various other causes. The matter does not seem to have been investigated with a view to obtaining a workable solution of the problem based upon the facts.

"As the American Consulting Engineers have formulated schedules of prices, and as doctors, lawyers, and architects often act together for the same end, it would seem to leave the average engineer free from

Resolution Regarding Appointment of Committee on Compensation of Engineers (continued).

any taint of being unprofessional if he also seeks some form of concerted action regarding his compensation.

"Since the Am. Soc. C. E. is representative of the engineering profession in this country, it would seem fitting that it should appoint a committee to investigate, tabulate, and interpret the facts in the case, and from these facts, point out a reasonable and just course of action for the Society to take in this matter. If the facts thus found indicate that a general increase in compensation is reasonable and just, it should be possible to also point out how to accomplish the result, and the Society should then take the action necessary for its accomplishment.

"I therefore submit the following motion for action of the Society at its January meeting:

"That the President appoint a Committee of eight members to look into the conditions of employment of Civil Engineers throughout the country, the compensation they receive, the duration of employment, the expenses for which they are re-imbursed by the employer, the expenses due to the work paid by the engineers themselves, the net yearly income, the prices charged for different classes of private work, and any other facts necessary to clearly set forth the problem. The report to set forth recommendations for action by the Society looking toward improving existing conditions and to include a report on the feasibility of this Society operating an employment bureau for its members covering all classes of engineering work. The Committee to consist of four employing engineers and four engineers holding subordinate positions. The Committee to be authorized to add to its membership and to fill vacancies. A preliminary report to be rendered in six months.

"I will be glad to accept any amendment to this motion which will facilitate obtaining the desired results.

"Respectfully submitted,

"Percival M. Churchill,

"Assoc. M. Am. Soc. C. E."

The Secretary.—Mr. Churchill has written and asked me to present that resolution in his name to this meeting.

The President.—It is presented to you, gentlemen, in the name of Mr. Churchill. If it is seconded it will be considered.

George S. Greene, Jr., M. Am. Soc. C. E.—I move that it be laid on the table.

Motion duly seconded.

The President.—It is moved and seconded that this resolution be laid on the table. Any remarks on that question?

Mr. Whinery.—It is a——

Gardner S. Williams, M. Am. Soc. C. E.—Allow me, Mr. President, to rise to a point of order. A motion to lay on the table is never debatable.

The President.—The Chair decides the point of order well taken. The vote is on the motion to lay it on the table. All in favor say "aye"; contrary, "no." The Noes appear to have it, and unless a division is called for, the Chair will so decide.

Mr. Whinery.—It is a departure from the method prescribed by the Constitution. The method prescribed by the Constitution for dealing with this question is that a motion shall be made to refer it to the Board of Direction. I move that the resolution be referred to the Board of Direction.

Mr. Williams.—I second the motion.

The President.—It is moved and seconded that the resolution be referred to the Board of Direction. Any remarks on the motion?

Mr. Herbert M. Wilson.—May we have a debate on the motion?

The President.—Yes, sir.

Mr. Wilson.—I would like to suggest that in referring this matter to the Board of Direction—which seems to be a proper method—that the Board be asked whether or not this motion is to be considered by them in the more narrow sense as applying to Civil Engineers, in the more restricted application of the title, or as to whether such a motion as this should not include the possibility of considering the matter of charges for all kinds of civilian engineers, electric, mechanical, mining, sanitary, etc., as well as Civil Engineers in the scientific sense.

I believe that as medical men of all kinds have got together, and lawyers in all kinds of practice have got together, it would seem to me that there might be a possibility of accomplishing something, if there should be a co-operative discussion of this matter by representatives of the other engineering professions. I make that suggestion.

The President.—That is made simply as a suggestion, not as an amendment. If it is not accepted by the mover of the original resolution it will not come before the meeting to vote on. Anything further to be said before the motion is placed, or any other motion? Those in favor of the motion to refer the matter to the Board of Direction will signify by saying "aye"; contrary, "no." It is carried.

The meeting is now open to any new business while we are awaiting the report of the tellers. I will say to Mr. Wilson that the matter he suggested about an hour ago would be in order now, if he wishes to present it under the head of new business.

Motion Regarding the Serving of Lunch at Annual Meeting.

Mr. Wilson.—I make a motion, Mr. President, to refer to the Board of Direction for consideration that the old practice, whereby those who visited the city had an opportunity to meet together at the noon hour on the first day of the Annual Meeting at luncheon here, be resumed.

The Society appears to have funds sufficient to pay for the refreshment, and is possibly in a position to serve this luncheon at noon, and thereby give us an opportunity to get together after the meeting.

Discussion Regarding the Serving of Lunch at Annual Meeting.

and go as a party from here to the various places which we are to visit. Of course, some reason which I have no knowledge of might have actuated the Society in suspending a year ago that time-honored practice. I make it as a motion for the Board of Direction to consider the possibility of resuming it.

The President.—Let me understand it. Is it that the Board of Direction be asked to consider a recurrence to that practice?

Mr. Wilson.—Yes.

A Member.—I do not think I really understand now what the motion is.

(Motion read, as follows: That the Board of Direction be asked to consider a recurrence to the practice of providing a luncheon on the first day of the Annual Meeting.)

The President.—It is a request to the Board of Direction to consider a return to the practice of having a luncheon here at the Annual Meeting. The Chair has not heard any seconder.

Mr. Williams.—I second it.

The President.—Any remarks to the motion.

The Secretary.—The tellers are not quite ready to report, and I think I might explain in a few words at least one of the reasons which has led to this change. I think I may say without any question that the amount of money that that luncheon cost has no bearing on the question. As a matter of fact, when that lunch was abandoned last year for the first time in the history of our Annual Meetings, every other function at the Annual Meeting was made free to all members and to the ladies of their families.

Many years ago the entire expense of the Annual Meeting entertainments was borne by voluntary subscriptions from Resident Members. Later the funds of the Society not being very large, a charge was always made for at least one, and sometimes for more than one, of the functions of the Annual Meeting, and in that way a sufficient amount of money was collected to pay at least part of the expenses of the meeting.

The reason for the abandonment of that luncheon is because we cannot furnish it to the number of members who come for it. Our resident membership has grown so that now it is almost 1 400; and engineers, as well as other people, when offered a free lunch, are apt to come to it. If, Mr. President, we only had to give luncheon to those who came here to-day to do business, and who attended this meeting, there would be no difficulty whatever; but at the last one of those luncheons, if I remember the figures correctly, we had about 850 to 900 people.

It is impossible to tell how many will come, and consequently you cannot tell how many to provide for; and if you knew you could not provide for them, because you have not the facilities for doing it in a

place of this kind. So it has been thought best by the various committees who have had charge of the arrangements for the Annual Meeting to abandon this luncheon, and to throw open all the other functions to all the members of the Society and their families, thus providing several free entertainments at which members can have that opportunity to meet each other which is impossible at the luncheon which has been abandoned.

Mr. FitzGerald.—Mr. President, as it seems desirable that we should kill a little time, while these arduous servants of ours (the tellers) are performing their duties, I want to add a word or two on this free lunch matter. Gentlemen, I belong to the old men; and I look back to those early days when we feared that we should hardly be able to make both ends meet at the end of the year.

Those were the halcyon days of the American Society of Civil Engineers; and now, gentlemen, when our income has grown so that we groan under its weight, let us not allow ourselves to enter into that decadent state which would tend to use it up in free lunches.

I appeal to you as serious minded members of the profession, is it wise for us to endeavor to eat up our surplus? Gentlemen, why not continue to let it grow in proportion to its diameter, and as it goes down hill, to grow and grow until finally those who are to succeed us will build here not a building of concrete but one of solid gold?

Allen Hazen, M. Am. Soc. C. E.—I am very much interested in this lunch proposition. I think we will all agree with our Secretary that there is not room in this house to serve a thousand people with collations in the way those collations have been served. We do not care so much what we have for lunch; it is the fact of having lunch, and having it while we are here together to see our friends and talk with them.

Now, I suggest that the Secretary next year provide chicken sandwiches for 1 200 people, or for as many as there is any reason to anticipate, and have waiters so that they can be served in a perfectly simple manner, and have no complicated features about it; and I think on that basis that the lunch can be served here.

A. P. Davis, M. Am. Soc. C. E.—As one who seconded that motion, I think the suggestion of Mr. Hazen is a good one, if it can be carried out; but I do not believe there is room enough here for 1 200 people to be served in any satisfactory manner.

However, the programme, as laid out for those who go to the subway in Brooklyn, and the reasons given therefor, are absolutely good, in my opinion, but throw an unjust burden on one member of this Society, or on a few friends, if he passes around the hat among them. But it has a practical benefit, having these people lunch together, who are going to the same places; it is the only practicable way of getting them together and having the programme of the afternoon carried out

Discussion Regarding the Serving of Lunch at Annual Meeting (continued).

promptly. If the members scatter for lunch it is almost impossible to get them together at any given hour, or in time to carry out a given programme in a satisfactory manner.

I believe this motion is broad enough, so that if referred to the Board of Direction, as it provides, it can consider, for the programme next year, four or five different luncheon places, such as the programme proposed in Brooklyn to-day, where luncheons can be served at the expense, not of a single member, or two or three resident members, which is unjust, but at the expense of the Society. Any inexpensive luncheon, such as Mr. Hazen describes, will be perfectly satisfactory to me, and to all the members; but it will be something that will get them together, not only for convenience in visiting the different places that are to be visited in the afternoon, but for the social attraction of the luncheon itself.

A chicken sandwich and a cup of coffee with a few engineer friends is a great deal more agreeable, and carries out the object of this Annual Meeting very much better, than scattering to different places, and thus delaying the meeting of the members for the trips.

There are five or six things to be done this afternoon by people who choose what they will do, and I have no doubt that a committee would find it entirely practicable to provide that many different luncheon places for those days, in order that the members may get together for these different functions.

I think, however, that the motion is broad enough so that that phase can be considered in its practicability and examined by the Board of Direction. I hope the motion will prevail.

The President.—Any further remarks upon this motion? You understand the motion. It is to refer to the Board of Direction the question of the advisability of returning to the old practice. All in favor of the motion say "aye"; contrary, "no." Carried.

Gentlemen, I am informed that the tellers are ready to report.

The Secretary.—No, sir.

The President.—I am very sorry to take that back.

The Secretary.—I was asking for an opportunity to kill more time. I do not believe that anybody knows the membership of this Society as well as I do; and I think that Mr. Hazen's suggestion is an extremely good one; but when he says that chicken sandwiches and coffee will satisfy all the members of this Society, he is mistaken. A slight amendment perhaps, though, would help; and I suggest that Mr. Hazen allow an addition to his motion by putting in just one little word, and that is "beer."

Mr. President, I do not know whether you want to kill any more time. It is all well enough to talk about these things as to what you can do, and what you cannot do; but there is one little difficulty that I would like to point out. Suppose we have three or four excursions in the afternoon, such as this afternoon, how can we tell how many

people to provide for at these various places where we are to meet, which will be convenient to the particular work the parties are going to see?

Let me tell you some of the difficulties that we have found with our present programme. At the excursion to the Bush Terminal to-morrow, a luncheon is to be furnished by the Turner Construction Company and by the Bush Terminal people, and they asked me to estimate how many people would be there. I told them I could not do that very well, but that we took more than 750 people out on the train to the Bethlehem Steel Company last year, when only 250 were expected, and I thought that was about the proportion.

As a matter of fact we had about 800 printed tickets for the Bush Terminal excursion, and they are all gone, and people are looking for more. It is almost impossible, no matter how you do it, whether by furnishing tickets or insisting upon people telling you beforehand, they will not do it, and you cannot provide for them; that is the principal difficulty.

As far as the luncheon which it has been customary to serve here is concerned, a great many people were disgruntled; they did not get enough to eat, and they did not get good service; and we had a great many complaints about it. You would be surprised how many. As I said before, if we could issue tickets—meal tickets or luncheon tickets—to the members who come to the Business Meeting and serve lunch only to them, there would be no trouble about it; but beyond that point it is almost impossible to do it here; and the chief difficulty is that you never can tell how many people are coming to any particular function.

I think from present returns we shall have about 850 here for the reception to-night. I think they can be taken care of very well, but the only way this can be done is to serve supper during the whole evening. It would not be possible to serve them all at the same time.

At the smoker there is every indication that the attendance may reach 1 000.

THE PRESIDENT.—Gentlemen, we will not adjourn, but we will give you a few minutes for conversation until the tellers are ready. Recess.

After recess.

THE PRESIDENT.—Come to order, gentlemen. The tellers are ready to make their report. It is in the hands of the Secretary. Ballot for Officers.

THE SECRETARY.—Mr. President, the Tellers, Messrs. A. H. Van Cleve, L. E. Moore, H. H. Quimby, H. S. Jacoby, H. N. Ogden, R. H. Brown, John G. Van Horne, C. W. Smith, R. V. Rose, and James Burden, report as follows:

Total number of ballots received	2 051
Not entitled to vote	21
Ballots counted	2 030

Ballot for Officers (continued).

For President:

John A. Ockerson	1 458
Richard Montfort	408
Scattering	9

For Vice-Presidents:

Charles S. Churchill	1 921
Charles D. Marx	1 881
Scattering	21

For Treasurer:

Joseph Moss Knap	2 017
Scattering	2

For Directors:

District No. 1	Lincoln Bush	1 417
	T. Kennard Thomson	1 194
	George S. Rice	916
	Scattering	10
District No. 4	Emil Gerber	1 930
	Scattering	9
District No. 6	William Cain	1 902
	E. C. Lewis	1 907
	Scattering	13
District No. 7	W. A. Cattell	1 914
	Scattering	30

Officers Elected.

The President asks me to announce that John A. Ockerson is elected President of the Society; Charles S. Churchill and Charles D. Marx, Vice-Presidents, Joseph M. Knap, Treasurer; and the following Directors: from the First District, Lincoln Bush and T. Kennard Thomson; from the Fourth District, Emil Gerber; from the Sixth District, William Cain and E. C. Lewis; and from the Seventh District, W. A. Cattell.

Remarks by Past-President Endicott.

The President.—I announce that the gentlemen named by the Secretary are elected your officers for the next year.

Gentlemen, in retiring from the Presidency, I wish to thank the Society for its kindness and consideration to me during my incumbency, and to say that the memories that I shall take with me as I retire will be among the most treasured of my life.

As you know, as Past-President, I shall continue to serve on the Board for five years; and if my life is spared during that time, I hope to give you the best service that is in me.

I will appoint Past-Presidents FitzGerald and Macdonald a committee of two to conduct the newly elected President to the Chair.

Remarks by President Ockerson.

President John A. Ockerson.—Fellow members of the Society, I have crossed the Continent to be with you on this occasion, to greet

you and to express my great appreciation of the honor that you have conferred on me.

With your assistance and your forbearance I hope that the incoming administration will conduct affairs so that you will have no reason to regret the choice that you have made.

Inasmuch as the tellers have devoted a great deal of time to counting the ballots, I do not think you want to hear a speech at this time. I thank you with all my heart.

THE SECRETARY.—Mr. President, might I make one or two announcements, if you please? I am requested to read the following: Announcements.

"The Washington members of this Society will give a banquet in Washington, Saturday evening, January 20th, in honor of the retiring and incoming Presidents of the Society. All members of the Society are invited. Tickets may be obtained by addressing J. C. Hoyt, M. Am. Soc. C. E., of the Geological Survey, Washington."

It is quite essential that there should be a meeting of the Board of Direction a little after the adjournment of this meeting, in the Secretary's office, on the first floor, to the right of the front door.

On motion, duly seconded, the meeting adjourned. Adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTY-NINTH ANNUAL MEETING

Wednesday, January 17th, 1912.—After the adjournment of the Business Meeting, at about 1 P. M., excursion parties were organized to visit the Aqueduct Shafts, the Grand Central Terminal Improvement, the Fourth Avenue Subway, and the Mount Prospect Laboratory:

Aqueduct Shafts.—Through the courtesy of J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer of the Board of Water Supply, an opportunity was given to inspect some of the shafts of the City Tunnel of the Catskill Aqueduct, and about 75 members descended Shaft 17 (223 ft.) to see the work in the headings. Other shafts were also visited.

Grand Central Terminal Improvement.—By the kindness of George W. Kittredge, M. Am. Soc. C. E., Chief Engineer of the New York Central and Hudson River Railroad, and G. A. Harwood, M. Am. Soc. C. E., Chief Engineer of the Electric Zone Improvements, a party of about 230, under the guidance of members of the Chief Engineer's staff, was enabled to inspect the Excavation work, Suburban level, Trucking subways, Pipe galleries, Track arrangement, Signal towers and apparatus, Service plant for light, heat and power, Steel erection, Express facilities, Shops, Terminal hospital, Station building, and many minor details of the Grand Central Terminal Improvement.

Fourth Avenue Subway, Brooklyn.—Through the courtesy of Alfred Craven, M. Am. Soc. C. E., Chief Engineer, Public Service Commission, and the kindness of the Bradley Contracting Company, about 115 members were conducted through several portions of the Fourth Avenue Subway. The members of this party met at the Hof Brau Haus, on Rockwell Place, Brooklyn, where they were entertained at lunch by W. N. Beach, Assoc. M. Am. Soc. C. E. After lunch the works were examined under the guidance of members of the engineering and contractor's staffs.

Mount Prospect Laboratory.—By the kindness of I. M. de Varona, M. Am. Soc. C. E., Chief Engineer of the Department of Water Supply, Gas and Electricity, an invitation was extended to visit the Mount Prospect Laboratory, and about 35 members took advantage of the opportunity to inspect the methods of making physical, bacteriological, and chemical examinations of water, analyses of coal, oil, etc., and tests of metals, paints, cement, and other construction material for the Department.

At 9 P. M. there was a Reception, with dancing, in the Society House, at which there were present 298 members and about 400 ladies and other guests.

Thursday, January 18th, 1912.—The day was devoted to an excursion to the Bush Terminal, in South Brooklyn. The steamer *Nassau*, with a large party left the pier at the foot of West 23d Street at 9.30 A. M., and, making a stop at Pier A, North River, sailed down the bay to the Bush Terminal docks, where a landing was made at about 11.30 A. M. After inspecting the piers, freight bridges, and some of the warehouses, the party assembled in one of the largest of the reinforced concrete loft buildings, where, by joint invitation of the Turner Construction Company and the Bush Terminal Company, the members were entertained at lunch. After lunch the various warehouses, loft buildings, etc., were inspected and many manufacturing processes were witnessed. The *Nassau* left the docks at 4 P. M., arriving at Pier A at about 4.40 P. M. and at West 23d Street at about 5.30 P. M. There were about 600 persons in this party.

In the evening, at the Society House, an informal "Smoker" was enjoyed by more than 800 members and guests.

The following list contains the names of 838 members who registered during the Annual Meeting. The list is incomplete, as many members failed to register, and it does not contain the names of any of the guests of the Society or of individual members. It is estimated that there was an attendance of 550 ladies and other guests, making the total attendance at the Annual Meeting more than 1 400:

Abbott, C. P......Valhalla, N. Y.
Abbott, Hunley...New York City
Aiken, W. A....Philadelphia, Pa.
Aims, W. I.......New York City
Alexander, H. J., White Plains, N. Y.
Allaire, D. A....Brooklyn, N. Y.
Allen, C. Frank....Boston, Mass.
Allen, C. R., Jr., Mechanicsville, N. Y.
Allen, J. M........Fulton, N. Y.
Allen, Kenneth...New York City
Alsberg, Julius...New York City
Andrews, G. C.....Fulton, N. Y.
Armstrong, R. S..New York City
Armstrong, R. W..New York City
Arnold, W. H.....New York City
Atkinson, Asher, New Brunswick, N. J.
Atwood, T. C.....Yonkers, N. Y.

Babcock, W. S....New York City
Baldwin, F. H....Bayonne, N. J.
Ball, L. A........New York City
Ballinger, W. F..Philadelphia, Pa.
Bamford, W. B....Belmar, N. J.
Bance, C. W....Jersey City, N. J.
Barbour, F. A......Boston, Mass.
Barker, C. W. T..Philadelphia, Pa.
Barker, J. M.....Pittsfield, Mass.
Barnes, H. E...Newburgh, N. Y.
Barnes, M G.......Albany, N. Y.
Barnes, T. H., West Medford, Mass.
Barnes, W. T........Chicago, Ill.
Barney, P. C......New York City
Barney, W. J.....New York City
Barrett, R. E......New York City
Barshall, F. B.....New York City
Barton, C. L......New York City
Basinger, J. G...Flushing, N. Y.
Bass, F. H....Minneapolis, Minn.
Baucus, W. I..North Adams, Mass.
Baum, George.....Yonkers, N. Y.
Baylis, A. R.....Brooklyn, N. Y.
Beach, W. N......New York City

Becker, R. C. . . . . . New York City
Beekman, J. V., Jr. . Boston, Mass.
Beggs, G. E. . . . . New York City
Belknap, W. E. . . . New York City
Bellows, S. R. . . . . New York City
Belzner, Theodore . . New York City
Benedict, F. M. . . . New York City
Bensel, J. A. . . . . . . Albany, N. Y.
Berger, Bernt. . . . . New York City
Berger, John. . . . . . New York City
Bettes, C. R. . Far Rockaway, N. Y.
Betts, F. K. . . . . . Kingston, N. Y.
Betts, R. T. . . . . . . New York City
Blair, C. M. . . New Haven, Conn.
Blakeslee, Clarence, New Haven, Conn.
Blakeslee, H. L. . Kitchawan, N. Y.
Blanchard, A. H. . New York City
Blatt, Max. . . . . New York City
Bleistein, B. J. . . . . Astoria, N. Y.
Boardman, H. S. . . . . Orono, Me.
Bogart, John. . . . . . New York City
Bogert, C. L. . . . . . New York City
Boller, A. P., Jr., East Orange, N. J.
Bolton, C. M. . . . . Millwood, N. Y.
Bond, G. M. . . . . . Hartford, Conn.
Boniface, Arthur. . Scarsdale, N. Y.
Booth, G. W. . . . . . New York City
Boughton, W. H., Poughkeepsie, N. Y.
Bouton, Harold. . . . New York City
Bowditch, J. H., New Brighton, N. Y.
Bowman, A. L. . . . New York City
Boyd, J. C. . . . . New York City
Boyd, R. W. . . . . . New York City
Brackett, Dexter. . . . Boston, Mass.
Brainard, A. S., East Hartford, Conn.
Braine, L. F. . . . . . New York City
Brainerd, H. A. . . Westfield, N. J.
Bramwell, G. W. . . New York City
Breed, C. B. . . . . Boston, Mass.
Breitzke, C. F. . . . . New York City
Breuchaud, Jules. . New York City
Briggs, H. A., Brown Station, N. Y.
Briggs, W. C., Richmond Hill, N. Y.
Brinckerhoff, A. G. New York City
Broadhurst, W. G., Hackensack, N. J.
Brodie, O. L., West New Brighton, N. Y.
Brogan, T. B. . . . . . New York City
Bromley, A. H., Jr., New York City
Brooks, J. N. . . . . . Trenton, N. J.
Brooks, J. P. . . . . . Potsdam, N. Y.
Brown, J. H., Jr. . New York City
Brown, P. G. . . . . . New York City
Brown, R. H. . . . . . New York City
Brown, S. P. . . . . . New York City
Brown, T. E. . . . . . New York City
Brunner, John. . . . . . Chicago, Ill.
Brush, W. W. . . . Brooklyn, N. Y.
Bryson, Andrew. . New Castle, Del.
Buck, H. R. . . . . . Hartford, Conn.
Buck, R. S. . . . . . . New York City
Buel, A. W. . . . . . . New York City
Buel, E. D. . . . . New York City
Burden, James. . . . . Oswego, N. Y.
Burdett, F. A. . . . . New York City
Burpee, G. W. . . . . New York City
Burr, W. H. . . . . . . New York City
Burroughs, H. R. . Brooklyn, N. Y.
Bush, E. W. . East Haddam, Conn.
Bush, Lincoln. East Orange, N. J.

Cadwallader, W. L. New York City
Cahn, Elias. . . . . . . New York City
Cain, William. . Chapel Hill, N. C.
Cameron, J. B. . . . . Somerset, Pa.
Cantwell, H. H. . . . Croton, N. Y.
Carey, E. G. . . . . . . New York City
Carmalt, L. J. . New Haven, Conn.
Carpenter, C. E. . . Yonkers, N. Y.
Carr, Albert. . . East Orange, N. J.
Casler, M. D. . . Mt. Vernon, N. Y.

Chadwick, C. R. . . New York City
Chappell, T. F. . . . New York City
Christian, G. L. . . . New York City
Christy, G. L. . . . . New York City
Church, E. C. . . . . . New York City
Churchill, C. S. . . . . Roanoke, Va.
Churchill, J. C. . . . Oswego, N. Y.
Clark, A. E. . . . . . . New York City
Clark, G. H. . . . . . . New York City
Clark, W. G. . . . . . . Tenafly, N. J.
Clarke, E. W. . Pleasantville, N. Y.
Clarke, G. C. . . . . . New York City
Cleveland, H. B. . . . Albany, N. Y.
Cleveland, L. B., Watertown, N. Y.
Codwise, H. R. . . . Brooklyn, N. Y.
Coe, Robert. . . . . Philadelphia, Pa.
Cohen, J. X. . . . . . . New York City
Colby, A. L., South Bethlehem, Pa.
Cole, G. N. . . . . New York City
Cole, H. J. . . . . New York City
Collier, B. C. . Pleasantville, N. Y.
Connell, H. L. . . . . New York City
Connell, W. H. . . . New York City
Cook, F. S. . . . . Yonkers, N. Y.
Coombs, A. W. . . . . New York City
Coombs, S. E. . . . . . Yonkers, N. Y.
Coomer, R. M. . . . Bay City, Mich.
Cooper, S. L. . . . . . Yonkers, N. Y.
Copeland, W. R. . . New York City
Corthell, A. B. . . Brookline, Mass.
Covert, C. C. . . . . . . Albany, N. Y.
Cowles, L. S. . . . . Boston, Mass.
Coyne, H. L. . . . . . New York City
Crane, A. S. . . . . . . New York City
Crane, J. S. . . . . Newark, N. J.
Craven, Alfred. . . . Yonkers, N. Y.
Cresson, B. F., Jr. . New York City
Creuzbaur, R. W. . New York City
Crooks, C. H. . . . . . New York City
Crosby, W. W. . . . Baltimore, Md.
Crowell, Foster. . . . New York City
Cuddeback, A. W. . Paterson, N. J.
Cummings, Noah. . New York City
Cummings, R. A. . Pittsburgh, Pa.
Cunningham, Stanley, Jr., New York City
Cunningham, W. A., Brooklyn, N. Y.
Cuntz, W. C. . . . . . New York City
Currier, C. G. . . . . New York City
Curtis, F. S. . . . . Boston, Mass.
Cutler, L. G. . . . . . New York City

Dahlin, J. E. B. . Edison Park, Ill.
Dailey, J. A. . . East Orange, N. J.
Dakin, A. H., Jr. . New York City
Darrow, M. S. . . . . . Maurer, N. J.
Darrow, W. J. . . . New York City
Davies, J. P. . . . . . New York City
Davis, A. P. . Washington, D. C.
Davis, B. H. . . . . . New York City
Davis, C. B. . . . . . New York City
Davis, C. E. . Brown Station, N. Y.
Davis, J. L. . . . . Yonkers, N. Y.
Day, W. E. . . . . Fort Banks, Mass.
Dean, A. W. . . . . Boston, Mass.
Dean, Luther. . . . . Taunton, Mass.
Deans, J. S. . . . . Phœnixville, Pa.
de Forest, N. B. . . . New York City
De La Mater, S. T. New York City
Dempster, O. J. . Little Falls, N. Y.
Dennis, W. F. . Washington, D. C.
Densler, F. H. . . . . Yonkers, N. Y.
de Varona, I. M. . New York City
de Wyrall, Cyril, Ridgefield Park, N. J.
Deyo, S. L. F. . . . New York City
Dibert, H. McM. . . . . . Troy, N. Y.
Dimon, D. Y. . . . . . . Passaic, N. J.
Dodwell, C. E. W. . Halifax, N. S.
Donle, E. R. . . . . . New York City
Dorrance, W. T. . . . Albany, N. Y.
Dougherty, R. E. . New York City
Doying, W. A. E., Washington, D. C.
Drowne, H. B. . . . . New York City
Dunham, H. F. . . . New York City
Durham, H. W. . . Sandwich, Mass.

Easby, M. W....Philadelphia, Pa.
Easterbrook, F. J., New Haven, Conn.
Eckersley, J. O...New York City
Eddy, H. P.....Worcester, Mass.
Edwards, D. G...Brooklyn, N. Y.
Edwards, H. W..New York City
Edwards, J. H.....Passaic, N. J.
Ehle, Boyd........Yonkers, N. Y.
Ehrbar, L. H......New York City
Eide, Torris.......New York City
Ellis, J. W.....Woonsocket, R. I.
Emerson, K. B...Brooklyn, N. Y.
Emery, J. A......New York City
Emory, L. T...Philadelphia, Pa.
Endicott, M. T..Washington, D. C.
Enger, A. L......Brooklyn, N. Y.
Entemann, P. M..Brooklyn, N. Y.
Erlandsen, O......Jamaica, N. Y.
Estabrook, G. M., Hempstead, N. Y.
Ewing, W. W.....Westfield, N. J.

Farnham, A. B...Pittsfield, Mass.
Farrington, H. P..New York City
Faucette, W. D..New York City
Fay, F. H.........Boston, Mass.
Federlein, W. G...New York City
Felgenhauer, F. J.Brooklyn, N. Y.
Ferguson, J. N.....Boston, Mass.
Ferguson, L. R..Philadelphia, Pa.
Finch, J. K.......New York City
Fisher, E. A.....Rochester, N. Y.
Fisher, Janon.....Eccleston, Md.
FitzGerald, Desmond, Brookline, Mass.
Fletcher, Robert..Hanover, N. H.
Flinn, A. D......Yonkers, N. Y.
Floesch, J. M....Rochester, N. Y.
Forbes, F. B......New York City
Ford, F. L......Hartford, Conn.
Ford, H. C.......New York City
Ford, W. G......Brooklyn, N. Y.
Forrest, C. N.....Maurer, N. J.
Fort, E. J.......Brooklyn, N. Y.
Foss, F. E.......New York City
Fougner, Hermann, New York City
Fowler, R. L.......Maurer, N. J.
Fox, J. A........San Diego, Cal.
Francis, G. B....New York City
Fraser, C. E......New York City
French, A. W....Worcester, Mass.
French, C. R....Wilkes-Barre, Pa.
French, J. B......New York City
Fuller, G. W......New York City
Fuller, W. E......New York City
Fulweiler, W. H., Westchester, Pa.
Furber, W. C....Philadelphia, Pa.

Gadd, R. F......Hartford, Conn.
Gahagan, W. H..Brooklyn, N. Y.
Gandolfo, J. H...New York City
Gardiner, F. W..Yonkers, N. Y.
Gardner, Warren..New York City
Gartensteig, Charles, New York City
Gaston, L. P....Somerville, N. J.
Gerber, Emil......Pittsburgh, Pa.
Gifford, G. E.....New York City
Gildersleeve, A. C., New York City
Giles, Robert......New York City
Gilfillan, G. A.....Pittsburgh, Pa.
Gill, H. E........Brooklyn, N. Y.
Gillen, W. J......New York City
Gillespie, R. H....New York City
Gilman, Charles..Plainfield, N. J.
Glander, J. H., Jr..New York City
Golding, T. W..Philadelphia, Pa.
Goldsborough, J. B., New York City
Goldsmith, Clarence, Boston, Mass.
Goodell, J. M.....New York City
Goodman, Louis...New York City
Goodrich, E. P....Brooklyn, N. Y.
Goodsell, D. B....New York City
Gould, C. M...Cold Spring, N. Y.

Gould, W. F......Hastings, N. Y.
Grady, C. B..West Orange, N. J.
Grantham, H. T..Philadelphia, Pa.
Green, C. N......New York City
Greene, Carleton...New York City
Greene, G. S., Jr., New York City
Greenfield, R. A., Mt. Vernon, N. Y.
Greenlaw, R. W...New York City
Gregory, C. E...Mt. Kisco, N. Y.
Gregory, J. H.....New York City
Griffith, W. F. R., Morristown, N. J.
Grimm, C. R.....Brooklyn, N. Y.
Grover, N. C..Washington, D. C.
Guthrie, K. O...Waterford, N. Y.

Haas, P. L...Poughkeepsie, N. Y.
Haight, S. S......New York City
Hale, H. M.......New York City
Hall, M. W.......New York City
Hall, R. E........Auburn, N. Y.
Hallock, J. C......Newark, N. J.
Hamilton, J. W...New York City
Hammel, E. F.....New York City
Hammel, V. F.....New York City
Hanavan, W. L..Newburgh, N. Y.
Hansel, Charles....New York City
Harby, Isaac...Forest Hill, N. Y.
Harding, H. S.....New York City
Harris, F. R.....Brooklyn, N. Y.
Harte, C. R....New Haven, Conn.
Hartman, A. F....New York City
Harwi, S. J.......Bayonne, N. J.
Haskell, E. E.......Ithaca, N. Y.
Haskins, W. J.....New York City
Hastings, E. M....Richmond, Va.
Hatch, F. N.......New York City
Hattan, W. C......Lexington, Va.
Hauck, William...New York City
Havens, R. D....Stamford, Conn.
Havens, V. L......Ewing, Nebr.
Hayes, H. W.......Boston, Mass.
Hazen, J. V......Hanover, N. H.
Hazen, W. N......Newark, N. J.
Healy, J. R.......New York City
Heilbronner, L. C., Schenectady, N. Y.
Helling, H. A., Poughkeepsie, N. Y
Hench, N. M.....Pittsburgh, Pa
Hendrie, J. F..Perth Amboy, N. J.
Hering, Rudolph...New York City
Herrmanns, F. E...New York City
Hewes, V. H......New York City
Hewitt, George....New York City
Higgins, C. H..Jersey City, N. J.
Higgins, J. W..Roselle Park, N. J.
Higginson, J. Y., New Rochelle, N. Y.
Hildreth, J. L., Jr., Cornwall, N. Y.
Hill, L. C.........Phœnix, Ariz.
Hilton, J. C., Shelburne Falls, Mass.
Hilts, H. E..New Rochelle, N. Y.
Himes, A. J......Cleveland, Ohio
Hirst, Arthur......Trenton, N. J.
Hitchcock, F. C...New York City
Hodgdon, B. A....New York City
Hodge, H. W......New York City
Hoff, Olaf.......Montclair, N. J.
Holbrook, A. R....New York City
Holtsmark, Erling, White Plains, N. Y.
Holtzman, S. F....New York City
Honness, G. G., Pleasantville, N. Y.
Houston, J. J. L..Jamaica, N. Y.
Hovey, O. E.....Plainfield, N. J.
Howard, J. L......Melrose, Mass
Howe, C. E......Hastings, N. Y.
Howell, W. A......Newark, N. J.
Howes, D. W...New Paltz, N. Y.
Hoyt, J. C....Washington, D. C.
Hubbard, W. D., West Shokan, N. Y.
Huber, W. L......Buffalo, N. Y.
Hudson, C. W....New York City

Hughes, H. J....Cambridge, Mass.
Hulburd, L. S., Seneca Falls, N. Y.
Hulsart, C. R.....New York City
Humphrey, R. L. Philadelphia, Pa.
Hunt, C. E.......New York City
Hunt, Charles Warren, New York City
Hunt, W. H......New York City
Hutchins, H. C....New York City
Hyde, J. L.......Westfield, Mass.

Ilsley, A. B....Washington, D. C.
Immediato, Gerardo, Montclair, N. J.
Ives, H. C......Worcester, Mass.

Jacoby, H. S......Ithaca, N. Y.
Janvrin, N. H...Newburgh, N. Y.
Jarrett, E. S......New York City
Jenkins, J. E.....New York City
Johannesson, Sigvald, Montclair, N. J.
Johnson, G. A...Montclair, N. J.
Johnson, T. H....Pittsburgh, Pa.
Jones, Pusey......New York City
Jones, S. R.......New York City
Jonson, E. F......New York City
Just, G. A., Long Island City, N. Y.

Kaestner, A. C....New York City
Karner, W. J.....New York City
Karnopp, E. B....Manãos, Brazil
Kastl, A. E........Albany, N. Y.
Kaufman, Gustave, Brooklyn, N. Y.
Keays, R. H....New Paltz, N. Y.
Keith, H. C.......New York City
Keller, O. B......New York City
Kelley, W. D......Yonkers, N. Y.
Kellogg, R. C....Brooklyn, N. Y.
Khuen, Richard...Pittsburgh, Pa.
Killam, C. W...Cambridge, Mass.
Kimball, F. C......Boston, Mass.
Kimball, G. A......Boston, Mass.
King, Wallace, Jr..New York City
Kinney, W. M....Pittsburgh, Pa.
Kinsey, W. A......Newark, N. J.
Kinsley, T. P......New York City
Kirkwood, H. C...New York City
Kittredge, G. W...New York City
Knap, J. M.......Catskill, N. Y.
Knickerbocker, C. E., New York City
Knight, F. B........Chicago, Ill.
Knighton, J. A....New York City
Knox, S. B........New York City
Kohn, A. H.......Lancaster, Pa.
Krause, L. G., Ventnor City, N. J.
Krellwitz, D. W...New York City
Kuchar, F. M.....New York City
Kuehnle, W. L...Brooklyn, N. Y.
Kuichling, Emil...New York City

Lamson, W. M....New York City
Landers, C. S......New York City
Lang, F. A........New York City
Lange, T. F.......New York City
Langthorn, J. S...New York City
Lannan, L. E..Mt. Vernon, N. Y.
Larmon, F. P...Cambridge, N. Y.
Larsson, C. G. E..Plainfield, N. J.
Latey, H. N......New York City
Latta, H. W....Philadelphia, Pa.
Lavis, Fred....Mt. Vernon, N. Y.
Ledoux, J. W....Swarthmore, Pa.
Lee, W. B........New York City
Leeuw, H. A., Yorktown Heights, N. Y.
Letson, T. H......New York City
Lewis, J. O......Brooklyn, N. Y.
Lewis, N. P.......New York City
Lieb, J. W., Jr....New York City
Llewellyn, F. T....New York City
Lobo, Carlos.....Brooklyn, N. Y.
Lockwood, W. F..Yonkers, N. Y.
Loewenstein, Jacob.New York City
Logan, W. S.....Arlington, N. J.

Look, M. J.,
Brown Station, N. Y.
Loomis, Horace. Mt. Vernon, N. Y.
Low, G. E......Maplewood, N. J.
Loweth, C. F........Chicago, Ill.
Lowinson, Oscar...New York City
Lucas, E. W. V. C.,
New York City
Ludwig, J. A.....New York City
Lynde, Clifford....Walden, N. Y.
Lynn, H. H. E....New York City

MacCracken, G. G. New York City
Macdonald, Charles,
New York City
MacFeeters, J. O. Brooklyn, N. Y.
MacGregor, R. A..New York City
Machen, H. B....New York City
Macksey, H. V..Dorchester, Mass.
McBurney, Henry..New York City
McComb, C. O....New York City
McComb, D. E....Havana, Cuba
McCurdy, H. S. R.,
Brown Station, N. Y.
McHarg, Leslie....New York City
McInnes, F. A......Boston, Mass.
McKenzie, T. H.,
Southington, Conn.
McKim, A. R.....New York City
McLure, N. R...Phœnixville, Pa.
McMenimen, W. V.,
Jersey City, N. J.
McMinn, T. J.....New York City
McMullen, R. W..New York City
McNulty, G. W...New York City
McPherson, R. H..New York City
Malcolm, C. W.......Urbana, Ill.
Malmros, N. L....New York City
Malmros, N. L. A..Yonkers, N. Y.
Maltby, F. B......New York City
Manahan, E. G....New York City
Manley, L. B.,
West Roxbury, Mass.
Marsh, A. L.......Newark, N. J.
Marshall, C. E. D.,
Garden City, N. Y.
Marshall, R. A...Cranford, N. J.
Matheson, E. G....New York City
Matheson, J. D.,
Winnipeg, Man., Canada
Mead, C. A.,
Upper Montclair, N. J.
Meadowcroft, William,
New York City
Mebus, C. F....Philadelphia, Pa.
Meem, J. C......Brooklyn, N. Y.
Meggy, R. L. G...Fanwood, N. J.
Mehren, E. J......New York City
Melius, L. L......New York City
Meriwether, Coleman,
New York City
Merrill, Ogden....New York City
Merriman, Thaddeus,
Essex Fells, N. J.
Merryman, W. C..New York City
Metcalf, Leonard...Boston, Mass.
Middlebrook, C. T..Albany, N. Y.
Miles, G. F.......New York City
Miller, Frank......Passaic, N. J.
Miller, H. A.......Boston, Mass.
Miller, R. P......New York City
Mogensen, O. E..Plainfield, N. J.
Moisseiff, L. S....New York City
Moler, W. G......New York City
Molitor, Frederic..New York City
Mönniche, T. B.,
Culebra, Canal Zone, Panama
Moore, F. F....Hawthorne, N. Y.
Moore, L. E...Newtonville, Mass.
Moore, S. W. East Elmhurst, N. Y.
Moore, W. H..New Haven, Conn.
Moorshead, A. L.,
Jersey City, N. J.
Morrison, H. J....Peekskill, N. Y.
Morse, C. M......New York City
Morse, W. L......New York City
Mould, G. A. H..Brooklyn, N. Y.
Moyer, Albert.....New York City
Mueser, William...New York City

Muller, Leslie.....New York City
Munkelt, F. H...Brooklyn, N. Y.
Murphy, J. L.....New York City
Musson, E. F....Norwich, N. Y.
Myers, C. H......New York City
Myers, J. H..White Plains, N. Y.

Neely, W. R....New Paltz, N. Y.
Nelson, G. A.......Lowell, Mass.
Newhall, H. L..New Paltz, N. Y.
Newman, R. M....Jackson, Mich.
Newton, J. P......Albany, N. Y.
Nichols, C. H..New Haven, Conn.
Noble, Alfred.....New York City
Norris, W. H......Portland, Me.
Norton, A. G..Middletown, N. Y.

Oakley, G. I...Little Falls, N. Y.
Obreiter, J. W....Hoboken, N. J.
Ockerson, J. A....St. Louis, Mo.
O'Connell, G. P.
Brown Station, N. Y.
O'Connor, J. A....Albany, N. Y.
Oestrich, H. L...Brooklyn, N. Y.
Ogden, H. N.......Ithaca, N. Y.
Ogden, J. C......Plainfield, N. J.
Okeson, W. R..East Orange, N. J.
Orr, Alexander.Gloversville, N. Y.
Orrok, G. A......Brooklyn, N. Y.
Ott, S. J......Hackensack, N. J.
Overocker, D. W.,
Canajoharie, N. Y.
Owen, A. E......Montclair, N. J.
Owen, James....Montclair, N. J.
Owen, K. D......Montclair, N. J.

Paddock, H. C....New York City
Palmer, S. B.....Norwich, Conn.
Parker, C. J......New York City
Parker, J. L.......Portland, Ore.
Parsons, H. A....Stamford, Conn.
Parsons, H. de B..New York City
Peabody, W. W.,
White Plains, N. Y.
Pegram, G. H.....New York City
Pellissier, G. E....New York City
Pelz, C. E........New York City
Pemoff, J. J.......New York City
Perkins, C. E.......Akron, Ohio
Perrine, George....New York City
Perry, J. P. H....New York City
Pfau, J. W.......New York City
Philips, J. H...Glen Ridge, N. J.
Pillsbury, F. C.....Boston, Mass.
Plogsted, W. J....New York City
Pohl, C. A........New York City
Polk, W. A.......Baltimore, Md.
Pollock, C. D.....New York City
Pond, H. O........Tenafly, N. J.
Poole, C. A......Rochester, N. Y.
Porter, J. E......Yonkers, N. Y.
Potts, Clyde....Morristown, N. J.
Powers, C. V. V...New York City
Pratt, A. H..White Plains, N. Y.
Preston, H. W.....Elmira, N. Y.
Price, C. P........Boston, Mass.
Price, P. L.,
Long Island City, N. Y.
Prichard, H. S...Pittsburgh, Pa.
Proctor, R. F...Philadelphia, Pa.
Purver, G. M....Brooklyn, N. Y.

Quimby, C. H., Jr.,
Mt. Vernon, N. Y.
Quimby, H. H..Philadelphia, Pa.
Quimby, J. H..East Orange, N. J.
Quincy, C. F......New York City
Quirk, J. F........Albany, N. Y.

Rankin, E. S......Newark, N. J.
Read, R. L........Malden, Mass.
Reed, C. S........New York City
Reichmann, A. F....Chicago, Ill.
Reid, H. A........New York City
Reimer, F. A..East Orange, N. J.
Reimer, W. H. V.,
East Orange, N. J.
Reynolds, L. C.........Erie, Pa.
Rhett, A. H......New York City
Rice, G. S........New York City

Richardson, Clifford, New York City
Richardson, J. D...Corona, N. Y.
Richardson, T. F..New York City
Ricker, G. A.......Buffalo, N. Y.
Ridgway, Robert, Poughkeepsie, N. Y.
Riegel, R. M......New York City
Rights, L. D......New York City
Ripley, Joseph.....Albany, N. Y.
Ripley, T. M.......Fulton, N. Y.
Robbins, F. H.....New York City
Roberts, H. W....New York City
Roberts, R. F..New Haven, Conn.
Robinson, E. F....New York City
Robinson, E. W...New York City
Rogers, E. H., West Newton, Mass.
Rohrer, Grant.....New York City
Ropes, Horace...Brookline, Mass.
Rose, R. V..Niagara Falls, N. Y.
Rosenthal, Albert, Mt. Vernon, N. Y.
Rossi, Irving...Jersey City, N. J.
Rourke, L. K.....Roxbury, Mass.
Rowntree, Bernard..Oradell, N. J.
Rue, M. A.......Brooklyn, N. Y.
Rugg, W. F......Peekskill, N. Y.
Ryan, M. H........New York City
Ryder, E. M. T....New York City
Ryon, Henry.....Brooklyn, N. Y.

Sanborn, F. B..Cambridge, Mass.
Sanborn, J. F..New Paltz, N. Y.
Sanborn, M. F., Pleasantville, N. Y.
Sando, W. J.....Milwaukee, Wis.
Sanford, H. C....New York City
Sanford, W. E...Brooklyn, N. Y.
Sargent, P. D..Washington, D. C.
Saville, C. M......New York City
Schaeffer, Amos...New York City
Schermerhorn, H. O..Troy, N. Y.
Schermerhorn, Richard, Jr., Brooklyn, N. Y.
Schlecht, W. W., Guayama, Porto Rico
Schmid, F. R.....New York City
Schmitz, F. C.....New York City
Schneider, C. C..Philadelphia, Pa.
Schreiber, J. M....Newark, N. J.
Scripture, A. M., New Hartford, N. Y.
Seabury, G. T....Valhalla, N. Y.
Seaman, H. B.....New York City
Seaman, W. H..Glen Cove, N. Y.
Searight, G. P., White Plains, N. Y.
Searle, L. F..Brown Station, N. Y.
Senior, F. S..Montgomery, N. Y.
Seurot, P. A......New York City
Shafer, J. C. F....New York City
Shaner, H. L.....Lynchburg, Va.
Shaughnessy, C. S., Cold Spring, N. Y.
Shaw, F. H.......Lancaster, Pa.
Shaw, G. H.....Brooklyn, N. Y.
Shedd, G. G......New York City
Shepherd, F. C..Brewerton, N. Y.
Sherman, A. L., White Plains, N. Y.
Sherrerd, J. M.......Easton, Pa.
Shertzer, T. B...Brooklyn, N. Y.
Shoemaker, M. N..Newark, N. J.
Sikes, Z. H.......Yonkers, N. Y.
Simpson, G. F....New York City
Simpson, P. D.......Bangor, Me.
Sitt, W. F........New York City
Skillin, E. S...Glen Ridge, N. J.
Skinner, F. W., Tompkinsville, N. Y.
Skinner, J. F....Rochester, N. Y.
Smith, Augustus..Bayonne, N. J.
Smith, C. B., Toronto, Ont., Canada
Smith, C. E.....Brooklyn, N. Y.
Smith, Charles W.Brooklyn, N. Y.
Smith, Chester W..Pulaski, N. Y.
Smith, E. F.......New York City
Smith, E. M......New York City

Smith, H. S....Wilkes-Barre, Pa.
Smith, J. R.......New York City
Smith, J. W......New York City
Smith, L. C. L.,
Long Island City, N. Y.
Smith, M. H......New York City
Smith, R. B......New York City
Smith, W. F......Valhalla, N. Y.
Smith, W. M., Sr..New York City
Smith, W. T......New York City
Smoley, C. K.......Scranton, Pa.
Snow, C. H........New York City
Snow, F. A........Boston, Mass.
Snyder, C. H......Oswego, N. Y.
Soest, H. C.......New York City
Spear, W. E.......New York City
Spelman, J. R.....New York City
Spencer, Herbert..Brooklyn, N. Y.
Spencer, T. N..Philadelphia, Pa.
Splitstone, C. H.,
East Orange, N. J.
Spofford, C. M......Boston, Mass.
Spooner, A. N..New Dorp, N. Y.
Sprague, E. L., Jr..Valhalla, N. Y.
Staniford, C. W..Brooklyn, N. Y.
Stanton, J. R.....New York City
Starr, H. H.......New York City
Stearns, F. P.......Boston, Mass.
Stearns, R. H.....New York City
Stehle, F. C..Mt. Vernon, N. Y.
Stephens, A. W.,
East Orange, N. J.
Stephenson, F. H..New York City
Stern, E. W......New York City
Stevens, E. W..Hackensack, N. J.
Stevens, H. C.....New York City
Stevenson, W. F..New York City
Stoddard, G. C....New York City
Stoddard, R. F..Bridgeport, Conn.
Stone, W. W....Newburgh, N. Y.
Stott, H. G........New York City
Stowe, H. C......Brooklyn, N. Y.
Stowitts, G. P.....New York City
Strachan, Joseph..Brooklyn, N. Y.
Strawn, T. C......New York City
Street, L. L....Dorchester, Mass.
Strickler, F. W....Meadville, Pa.
Strickler, G. B.,
Fredericksburg, Va.
Strong, J. B.....Hillburn, N. Y.
Strong, M. R......New York City
Stuart, A. A.....Brooklyn, N. Y.
Sutton, C. W........Chester, Pa.
Sutton, Frank..Washington, D. C.
Swensson, Emil...Pittsburgh, Pa.
Swift, A. C......Red Bank, N. J.
Swindells, J. S..Brooklyn, N. Y.

Taber, G. A.....Brooklyn, N. Y.
Taggart, R. C.....New York City
Tait, Harold,
Long Island City, N. Y.
Tait, J. G.......Metuchen, N. J.
Talbot, Earle........Utica, N. Y.
Tallman, T. B..East Orange, N. J.
Taylor, C. F......New York City
Teal, J. E........Baltimore, Md.
Temple, W. H. G.Providence, R. I.
Tenney, W. R....Brooklyn, N. Y.
Thacher, Edwin....New York City
Thoma, Jacob,
Long Island City, N. Y.
Thomas, C. D....Brooklyn, N. Y.
Thomes, E. H....Jamaica, N. Y.
Thompson, J. A...New York City
Thompson, S. C...New York City
Thompson, W. L..Brooklyn, N. Y.
Thomson, Alexander, Jr.,
Walden, N. Y.
Thomson, John....New York City
Thomson, S. F..New Paltz, N. Y.
Thomson, T. K....New York City
Thornley, Julian...New York City
Thrane, M. M....Pittsfield, Mass.
Tidd, A. W..White Plains, N. Y.
Tighe, J. L.......Holyoke, Mass.
Tillson, G. W....Brooklyn, N. Y.
Tombo, Carl......New York City
Tompkins, E. DeV..Pelham, N. Y.
Tompson, G. M..Wakefield, Mass.

Torrance, W. M...New York City
Tower, J. W......New York City
Townsend, C. McD..Detroit, Mich.
Tozzer, A. C......New York City
Trautwine, J. C., Jr.,
Philadelphia, Pa.
Tribus, L. L......New York City
Triest, W. G......New York City
Trout, C. E.......New York City
Trow, F. H..Brown Station, N. Y.
Trowbridge, D. S..New York City
Tudbury, W. C....New York City
Tull, R. W........New York City
Turner, D. L......New York City
Turner, E. K.......Boston, Mass.
Turner, H. C.....New York City
Tuttle, A. S.......New York City
Tyler, W. R.........Austin, Tex.

Ulrich, Daniel....Katonah, N. Y.
Underwood, H. W.,
Philadelphia, Pa.
Ungrich, M. J.....New York City
Upson, M. M....Englewood, N. J.
Upton, Joseph....Flushing, N. Y.

Vallely, W. P.....New York City
Van Cleve, A. H..New York City
Van Horne, J. G..New York City
Van Horne, J. R..New York City
Van Winkle, Edward,
Brooklyn, N. Y.
Van Winkle, E. B.New York City
Vaughan, L. B...Kingston, N. Y.
Verveer, E. L.....New York City

Waddell, F. C.,
West New Brighton, N. Y.
Wadsworth, J. E..New York City
Wagner, J. C...Philadelphia, Pa.
Wagner, S. T...Philadelphia, Pa.
Wait, B. H.......New York City
Walker, C. I......New York City
Walker, E. D...State College, Pa.
Walker, E. L......New York City
Wallace, J. F.....New York City
Ward, C. D.......New York City
Wardle, E. B......New York City
Warnock, W. H...New York City
Warren, H. A.....Baltimore, Md.
Wason, L. C.....Brookline, Mass.
Watkins, F. W.,
White Plains, N. Y.
Webster, G. S..Philadelphia, Pa.
Wegmann, Edward.New York City
Wells, C. E......Yonkers, N. Y.
Wescott, J. V.......Chicago, Ill.
Weston, R. S......Boston, Mass.
Weymouth, Aubrey,
New York City
Wheatcroft, H. B., Jr.,
New York City
Whinery, Samuel,
East Orange, N. J.
Whiskeman, J. P..New York City
White, Lazarus....New York City
White, W. M......New York City
Whitson, A. U.Cold Spring, N. Y.
Whittemore, D. J.,
Poughkeepsie, N. Y.
Whittier, T. T....New York City
Wiggin, T. H....Scarsdale, N. Y.
Wilkins, W. G....Pittsburgh, Pa.
Williams, G. S..Ann Arbor, Mich.
Willis, A. J.,
South Bethlehem, Pa.
Wilmot, James..Providence, R. I.
Wilmot, Sydney.Providence, R. I.
Wilson, C. T.....New York City
Wilson, C. W. S.,
New Rochelle, N. Y.
Wilson, H. M....Pittsburgh, Pa.
Wilson, P. H....Philadelphia, Pa.
Wilson, W. T.....New York City
Winsor, F. E.White Plains, N. Y.
Winsor, G. A.....Valhalla, N. Y.
Winsor, H. D.....New York City
Wise, C. R ......Passaic, N. J.
Wise, R. S........Passaic, N. J.
Witmer, F. P..East Orange, N. J.

Wittstein, H. L. .New Haven, Conn.
Wolff, A. D., Jr. . . New York City
Wood, G. P. . . . . . Peekskill, N. Y.
Wood, H. S. . . . . . . New York City
Woodard, S. H. . . Scarsdale, N. Y.
Woodworth, R. B. . Pittsburgh, Pa.
Worcester, J. R. . . . Boston, Mass.
Wortendyke, N. D.,
Jersey City, N. J.
Wright, J. B. . Amsterdam, N. Y.
Wyckoff, C. R. . . . Brooklyn, N. Y.
Wyman, A. M. . . . New York City

Yates, J. J. . . . . . Plainfield, N. J.
Yates, P. K. . . . . . . New York City
Yereance, W. B. . . New York City

Zipser, M. E. . Poughkeepsie, N. Y.

FINAL REPORT OF THE SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT.

THE PRESIDENT AND MEMBERS,
AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN:—At the Annual Meeting, held January 18th, 1911, your Committee on Uniform Tests of Cement submitted a final report, as required by resolution passed at the preceding Annual Meeting, and stated that it seemed possible, by conference with a Board of Engineers to be appointed by the Chief of Engineers of the United States Army, to agree upon methods approved by both the Board and your Committee, which it was believed would result in uniform practice by all engineers in the United States; the Society thereupon continued the Committee for one year.

The Army Board was duly appointed, its membership including one of the members of your Committee. Conferences were held or hearings given as follows:

On September 12th, 1911, a hearing was given by the Army Board in New York, attended by representatives of your Committee, by a representative of one of the commercial testing laboratories, by a representative from the United States Bureau of Standards, and by several manufacturers. It appeared at this hearing that a tentative specification for methods of testing had been prepared by representatives of several bureaus in Washington, adopting the methods recommended in previous reports of your Committee, except in regard to the determination of normal consistency and time of setting of cement pastes. Upon the request of your Committee two additional conferences were held, one on November 27th, 1911, the other on January 8th, 1912, with the hope on the part of your Committee of reaching entire agreement, but without favorable result.

In submitting this, its final report, your Committee desires to describe, in some detail, the differences between the proposed methods of making these tests, and to state on these points the reasons for its final recommendations, and to refer to the current practice in this and other countries.

The Vicat apparatus, which is recommended by your Committee for the determination of consistency and time of setting, was originally devised by Vicat about 1818, to ascertain the relative rates of induration of mortars, and although it has since been slightly modified to make it more suitable for determining the time of setting of plastic mortars of neat cement, the principle of the apparatus, the vertical guiding of a weighted wire, remains unchanged. The ball method for

determining normal consistency, which has been adopted by the Army Board, is not new, but was used in France before the adoption of the Vicat apparatus for this purpose. The relative merits of the two methods were investigated, with many comparative experiments, by a Commission on Methods of Testing Materials of Construction appointed by the Government of France in 1891. As a result of this investigation, the Commission in 1893 adopted the Vicat apparatus for determining normal consistency; it has since been adopted by the International Association for Testing Materials, and in many countries, as will be shown further on in this report.

The so-called Gillmore wires appear to have been first proposed by M. Antoine Racourt, to whom Gen. Jos. G. Totten, Hon. M. Am. Soc. C. E., refers in his translation of "Essays on Hydraulic and Common Mortars, etc.," by Treussart and others, published in 1842. Gen. Q. A. Gillmore, M. Am. Soc. C. E., in his "Practical Treatise on Limes, Hydraulic Cements, and Mortars" refers to these wires as having been used by Gen. Totten prior to 1830, and recommends their use for determining time of setting; it does not appear that they have ever been used for determining normal consistency, for which purpose they are not suitable.

When your Committee began the duty assigned to it, it took into consideration the ball method and the Vicat apparatus for testing consistency. A great many tests were made by the members of the Committee to determine the relative value of these methods, after which the method by use of the Vicat apparatus was formulated, and the Committee proceeded to test it in comparison with other methods in common use. The tests were arranged to include a comparison of the method of mixing pastes and mortars and moulding test pieces recommended by the Committee with other methods. Accordingly a meeting was held at the laboratory of the Atlantic Avenue Improvement of the Long Island Railroad, under the direction of your Committee, and in the presence of several of its members, at which were present representatives of seven laboratories of recognized standing. The cement was prepared carefully by mixing with a garden rake on a clean papered floor; then sifting in long thin layers one on top of the other and again mixing with the rake and sifting into a barrel from which it was used. The operators were all experienced in testing cement, and, with a single exception, were accustomed to daily practice; those who took part assembled in an outer room, from which each in turn entered the laboratory where he made determinations for consistency and also made a set of 20 briquettes, all in accordance with the Committee's methods, and at the same time made a set of ten briquettes in accordance with his own method. For the purpose of uniformity, the weighing of the cement and measuring of the water was done by one person while the manipulation of the Vicat apparatus was entrusted

to another. After completion of his work each operator remained in the laboratory, affording no opportunity for exchange of views with those who had not performed the experiments. The briquettes were all kept under the same conditions, stored in moist air for 24 hours, and then immersed in water and kept at a temperature as near 70° Fahr. as possible, and after a specified period were removed from the water, the excess moisture absorbed by blotting paper, the briquettes weighed and broken. The result of these tests showed that the several operators agreed as to the proper percentage of water required for normal consistency determined by the Vicat apparatus. In making briquettes by their own methods the operators used different consistencies, from wet paste to material so dry that it required pounding in the mould with a mallet, the percentage of water varying from 16 to 24%; more consistent results were obtained with the Committee's consistency and by the methods recommended by the Committee than with the methods of the operators.

Arrangements were then made for another series of experiments with five samples of Portland cement and four samples of natural cement, carefully prepared as before described, hermetically sealed in tin cans and sent to some 26 testing laboratories in various part of the country with a request to test the cements on a given date in accordance with the methods formulated by your Committee, and to report the results to the Secretary on certain dates. These results were collated and a study showed such agreement in regard to consistency, strength, and other tests as to satisfy the Committee that by its methods concordant results could be secured by different operators in different parts of the country. In order to compare the ball test for normal consistency with the Vicat apparatus method, samples of cement were prepared and sent out to several members of the Committee; simultaneous tests of the two methods were made, and the results were conclusive, the Vicat apparatus giving more concordant results than the ball method. The Committee does not wish it to be inferred that any method yet proposed for determining consistency will always prove exact, for no such method has been devised, but it does fully believe that, by the method recommended, operators in different parts of the country can secure more concordant results than can be obtained by any other method yet proposed.

The Army Board has adopted the ball test, which was recently defined as follows:

"A quantity of cement paste should be mixed in the manner hereinafter described under Tensile Tests and quickly formed into a ball about 2 in. in diameter. The ball should then be dropped upon a hard, smooth surface from a height of 2 ft. The paste is of normal consistency when the ball does not crack and does not flatten more than one-half of its original diameter."

The ball test in some form has been in use for many years as a rough and ready means of judging the consistency of mortar. Quite recently a number of experiments with the test were made under the direction of the Committee by experts in testing cement, with the result that variations in the percentage of water amounting to 2 or 3% of the weight of the cement, or about 10 to 15% of the weight of the water, might not be detected by this test of consistency.

The method of forming the ball can hardly be defined so that the work put on the paste by different operators in shaping it will be the same; if the ball is oblong, rather than spherical, the amount of flattening will depend considerably on whether the ball is dropped with the longer or shorter axis vertical. The specification above quoted may be made much more definite in this respect, and the amount of flattening can be better defined; such changes may have been made in the more recent revisions by the Army Board, but even with this assumed your Committee is convinced that the test it recommends is the better; it requires less time for the preparation of the sample of paste, but, on the other hand, the application of the cylinder requires more time than dropping the ball, and the complete test with the Vicat apparatus may require a little more time than the ball test. The difference, however, is not important, since either test is quickly made, and the cost is trifling.

The percentage of water adopted by the Army Board for mortars containing one part of cement to three parts of Ottawa sand is uniformly 1% greater than recommended by your Committee. Additional experiments made recently by your Committee, confirm its previous recommendation.

In the tests for time of setting it is sought to determine two stages in the process, one when the paste ceases to be plastic, termed the "initial set," the other when it will support a given weight on a given area, termed the "final set." Neither term is absolutely correct, particularly the term "final set"; each as used depends largely on the instrument for making the test, but with this stated and its application carefully described and followed the terms become readily understood.

Your Committee recommends the use of the Vicat needle for determining these stages, while the Board of Army Engineers adopts the Gillmore needles. It is believed that the phrase, "Vicat needle apparatus" has given the incorrect impression of complexity. The apparatus consists simply of a single rod of given weight and given diameters at the ends, moving vertically in a guide; in its use, the end of the rod is brought into contact with the paste and held lightly by a thumb-screw, then released with a minimum of vibration or jarring. The Gillmore needles are wires of given diameters carrying given weights; two are required for determination of time of setting; they are applied by hand, without guides, and the results depend much

on the steadiness of hand and the skill of the operator. It seems to your Committee that there should be no doubt that the Vicat needle is the better instrument; although slightly more expensive, it does not increase the cost of a laboratory equipment more than 3 or 4 per cent.

Of the two stages in the process of setting, the initial set is of the greater importance, since it marks the moment when the setting becomes appreciable, and it is generally believed that if the paste is broken up after this stage is reached its final strength will be reduced. In the method recommended by your Committee the sample for testing is formed from the paste with a minimum of manipulation; care is taken not to compress the paste, and the surface to which the needle is to be applied is formed by slicing off the paste above a given thickness of sample without pressure upon the sample, the condition of the paste at the surface being identical with that in the mass. The thickness of the mass is a little more than 1½ in. and is a definite quantity. When the sample is first formed, the Vicat needle penetrates readily through the entire thickness or depth of the mass; as the setting proceeds, a moment arrives when the needle no longer penetrates entirely through, but stops when within a short, specified distance from the lower surface. This is taken as the initial set. For such a test it is obvious that the movement of the needle must be guided, for unsteadiness in its lateral support would have a great influence on the amount of penetration. For the application of the Gillmore needle, a thin pat (about ½ in. thick) is formed on a glass plate by troweling. The amount of troweling does not admit of clear definition, and will vary widely with different operators. It is a matter of common observation that a troweled surface differs much in density from the mass, and in the pats for the Gillmore needles this difference will be highly variable because of the difference in troweling. This is important, since the initial set is determined with the Gillmore needle not by penetration of the mass, but by a slight indentation of its surface; thus depending, not only on the chemical action of setting, but on the variable physical preparation of the surface, as well as on the variable condition of the atmosphere, which will affect a surface more than a mass.

It has been stated that the Gillmore needle test requires less time. There can be no question that the Vicat sample for testing is more quickly formed than the Gillmore pat, while a single application of the Gillmore needle will require less time than the Vicat needle; if a single test were made at the specified limit of time, to determine simply whether the initial set had occurred, the Vicat test would be the quicker; if repeated applications of the needle were made to ascertain at what moment the set occurred and the number of applications were large, the Vicat method might require more time. The

difference would be small if the Gillmore needle were used with great care, and would not be important in any case.

In the judgment of your Committee the determination of initial set is of much importance, and is much better done with the Vicat needle used in the manner it recommends; in the determination of normal consistency, however, the superiority of the Vicat method over the ball method, while appreciable, is less marked.

The determination of final set is of less importance than the determination of initial set; in both methods the test is of indentation, not penetration, the difference being mainly in the nature of the surface tested. For reasons already given, the surface of the sample used with the Vicat needle represents the mass more fairly than the troweled surface of the pat used with the Gillmore needle.

Your Committee in its endeavor to reach an agreement with the Army Board offered to accept the less desirable ball method for determining normal consistency if the Board would adopt the Vicat needle for time of setting. By the rejection of this offer, your Commitee was brought to the question whether, for the sake of complete agreement with the Army Board, substantial agreement having already been reached, it would recommend for the test of time of setting a method which it believed to be greatly inferior in regard to an important test, constituting a decided retrogression in methods for testing cement.* The methods of the Army Board have the concurrence of a departmental committee representing several branches of the United States Government, and your Committee, having asked at the last Annual Meeting for an extension of time in order to secure uniformity in methods, felt strongly the desirability of effecting entire agreement, and has given the questions of difference renewed and most earnest consideration.

The Vicat apparatus recommended by your Committee in its first preliminary report in 1903, had been in use for many years in many laboratories and had been thoroughly tried out in the laboratory of the City of Philadelphia. Since 1903 its use has been greatly extended. Previous to the last Annual Meeting, the Secretary of this Committee addressed a letter of inquiry to testing laboratories in the United States, and received replies from 143; of these, 93 reported the use of the methods recommended by your Committee, and 72 reported them very satisfactory; 12 were from Army Engineers who used the methods prescribed by the Engineer Corps in Professional Paper 28; 30 used their own methods, and 8 reported that they did not make cement tests; of the total number of replies, 19 used the Gillimore needles and 114 used the Vicat apparatus; 2 used their own

* One member of the Committee has expressed dissent from this statement of the case, and believes that from a practical point of view the results obtained by the ball method for determining normal consistency and the Gillmore needles for time of setting are as satisfactory as those given by the Vicat apparatus.

methods, and the remainder, as previously stated, did not make cement tests.

The method recommended by your Committee being thus supported in this country, the practice in foreign countries was investigated, with the following results:

Summary of Methods Specified for Determining Time of Setting and Normal Consistency in Foreign Countries.

Country.		Time of Setting.	Normal Consistency.
Belgium	(*a*)	Vicat Needle.	Vicat Apparatus.
Denmark	(*b*)	" "	" "
France	(*a*)	" "	" "
Holland	(*c*)	" "	" "
Hungary	(*d*)	" "	" "
Italy	(*a*)	" "	" "
International Assn. Test. Mats.		" "	" "
Russia	(*e*)	" "	" "
Austria	(*d*)	" "	Boehme Hammer Apparatus.
Germany	(*a*)	" "	" " "
Switzerland	(*f*)	" "	" " "
England	(*g*)	" "	Note 1.
Canada	(*h*)	Note 2.	Note 3.

(*a*) Ministry of Public Works.
(*b*) Danish States Testing Laboratory.
(*c*) Royal Institute of Engineers.
(*d*) Association of Engineers and Architects.
(*e*) Ministry of Ways and Communications.
(*f*) Ministerial Regulations.
(*g*) Engineering Standards Committee.
(*h*) Canadian Society of Civil Engineers.

Note 1.—The cement shall be mixed with such proportion of water that the mixture shall be plastic when filled into the Vicat mould. The gauging shall be completed before the signs of setting occur.

Note 2.—The cement shall be considered as having taken "initial set" when a wire $\frac{1}{12}$ in. in diameter, loaded to weigh $\frac{1}{4}$ lb., shall leave a distinct mark on the pat, but not appreciably penetrate the surface, and the "final" or "hard set" when a wire $\frac{1}{24}$ in. in diameter, loaded to weigh 1 lb., shall leave a distinct mark, but not appreciably penetrate the surface.

Note 3.—For a cement 75% of which will pass a No. 200 sieve, a maximum of 22% of water, and an additional 1% of water for each extra 5% of cement that will pass the No. 200 sieve.

Your Committee would direct attention to the Report of The Engineering Standards Committee of England, supported by:

The Institution of Civil Engineers,
The Institution of Mechanical Engineers,
The Institution of Naval Architects,
The Iron and Steel Institute,
The Institution of Electrical Engineers,

dated August, 1910, containing a revision of the British Standard Specifications for Portland Cement, in which the following statement is to be found concerning the determination of the time of setting:

"Since the issue of the first revision of the Specification the Committee has continued its investigation into the question of the determination of the initial setting time of cement. It was found that while the final setting times determined by the British Standard and Vicat Needles approximated very closely, the initial setting time as determined by the British Standard Needle differed considerably from that given by the Vicat needle which is in general use, and also from that obtained by the rough and ready test of the finger nail.

"It was considered preferable that one instrument only should be specified for determining the initial and final setting times of cement, and the Vicat Needle has been adopted for that purpose."

By this action a modified form of the Gillmore needle was superseded.

At the Sixth International Congress for Testing Materials, held at Copenhagen in 1909, an official report on the progress in methods of testing hydraulic cements was presented by R. Feret, Ingénieur en Chef, Laboratoire d'Essai des Ponts et Chaussées, at Boulogne sur Mer. In this report M. Feret makes the following comments on methods for determining the duration of setting:

"The use of the Vicat needle continues to be the only practical method in use for the determination of the duration of the period of setting of hydraulic cements. The appliance is one of extreme simplicity, but its readings are sometimes uncertain, especially when it is a question of determining the end of the period; besides the readings are of a purely conventional character and do not appear always to bear a sufficiently constant relation to the duration of the setting period of the mortars of actual practice.

"The discovery of more exact methods has therefore been attempted."

Attention is further called to a paper by W. C. Reibling and F. D. Reyes, on "The Setting Properties of Portland Cement," contained in Vol. VI, No. 3, Section A, June, 1911, of the *Philippine Journal of Science,* published by the Bureau of Science of the Philippine Government, in which the authors make the following comments on the Vicat apparatus:

"Throughout our work, several standard methods were employed for determining the time of the initial and final set. The method employing the Vicat needle as adopted by the American Society for Testing Materials was found to be the most consistent with the manner in which the cement is used in actual work. It is reliable, impartial and accurate."

In view of all this evidence, the Committee does not feel justified in modifying its previous recommendation of the Vicat apparatus.

The methods recommended by your Committee imply the use of well-equipped laboratories, such as are now usually found in connection with large works of construction, and it is believed they are described in sufficient detail to enable skilled operators to obtain concordant results without communicating with one another. This is shown by comparing past and present practice in regard to normal consistency. When your Committee began its work, the consistency adopted in the different laboratories had a wide range, from very soft to very dry paste; now the practice is virtually uniform in the United States, and this is due, the Committee firmly believes, to the general use of the methods recommended by it in previous reports, or, in other words, to training with the Vicat apparatus.

Where the construction work is of small extent, field tests of less definite character will be made, depending on the facilities and time available. These are so variable in extent and kind, and can be so readily specified by the Engineer, that it has not been deemed advisable or practicable to enumerate and describe them.

Since its last report your Committee has made several verbal changes in its recommendations. Methods for igniting cement and for determining insoluble residue have been inserted, although it is apprehended that the latter determination may prove to be of little value. The Committee now recommends the clip with roller points, which has been used successfully and by which central breaks may be obtained in most cases. The final recommendations are submitted herewith. As in former reports, the significance of each test is stated, as well as the method of carrying it out.

For the convenience of engineers who may desire to incorporate in their specifications the methods recommended, a condensed draft is also submitted, in which discussion is omitted.

In accordance with the resolution passed at the last Annual Meeting, the duty of this Committee is concluded with this report.

Respectfully submitted on behalf of the Committee,

George S. Webster, *Chairman.*

Richard L. Humphrey, *Secretary.*

January 17th, 1912.

METHODS FOR TESTING CEMENT.*

Sampling.

1.—*Selection of Sample.*—The selection of samples for testing should be left to the engineer. The number of packages sampled and the quantity taken from each package will depend on the importance of the work and the facilities for making the tests.

2.—The samples should fairly represent the material. When the amount to be tested is small it is recommended that one barrel in ten be sampled; when the amount is large it may be impracticable to take samples from more than one barrel in thirty or fifty. When the samples are taken from bins at the mill one for each fifty to two hundred barrels will suffice.

3.—Samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; the use of this sieve is also effective to obtain a thorough mixing of the samples when this is desired. To determine the acceptance or rejection of cement it is preferable, when time permits, to test the samples separately. Tests to determine the general characteristics of a cement, extending over a long period, may be made with mixed samples.

4.—*Method of Sampling.*—Cement in barrels should be sampled through a hole made in the head, or in one of the staves midway between the heads, by means of an auger or a sampling iron similar to that used by sugar inspectors; if in bags, the sample should be taken from surface to center; cement in bins should be sampled in such a manner as to represent fairly the contents of the bin. Sampling from bins is not recommended if the method of manufacture is such that ingredients of any kind are added to the cement subsequently.

Chemical Analysis.

5.—*Significance.*—Chemical analysis may serve to detect adulteration of cement with inert material, such as slag or ground limestone, if in considerable amount. It is useful in determining whether certain constituents, such as magnesia and sulphuric anhydride, are present in inadmissible proportions.

6.—The determination of the principal constituents of cement, silica, alumina, iron oxide, and lime, is not conclusive as an indication of quality. Faulty cement results more frequently from imperfect preparation of the raw material or defective burning than from incorrect proportions. Cement made from material ground very finely and thoroughly burned may contain much more lime than the amount

* Accompanying Final Report of Special Committee on Uniform Tests of Cement, dated January 17th, 1912.

usually present, and still be perfectly sound. On the other hand, cements low in lime may, on account of careless preparation of the raw material, be of dangerous character. Furthermore, the composition of the product may be so greatly modified by the ash of the fuel used in burning as to affect in a great degree the significances of the results of analysis.

7.—*Method.*—The method to be followed should be that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, reported in the *Journal* of the Society for Chemical Industry, Vol. 21, page 12, 1902; and published in *Engineering News,* Vol. 50, p. 60, 1903; and in *Engineering Record,* Vol. 48, p. 49, 1903, and in addition thereto, the following:

The insoluble residue may be determined as follows: To a 1-gramme sample of the cement are added 30 cu. cm. of water and 10 cu. cm. of concentrated hydrochloric acid, and then warmed until the effervescence ceases, and digested on a steam bath until dissolved. The residue is filtered, washed with hot water, and the filter paper and contents digested on the steam bath in a 5% solution of sodium carbonate. This residue is filtered, washed with hot water, then with hot hydrochloric acid, and finally with hot water, and then ignited at a red heat and weighed. The quantity so obtained is the insoluble residue.

Specific Gravity.

8.—*Significance.*—The specific gravity of cement is lowered by adulteration and hydration, but the adulteration must be considerable to be detected by tests of specific gravity.

9.—Inasmuch as the differences in specific gravity are usually very small, great care must be exercised in making the determination.

10.—*Apparatus.*—The determination of specific gravity should be made with a standardized Le Chatelier apparatus. This consists of a flask (*D*), Fig. 1, of about 120 cu. cm. capacity, the neck of which is about 20 cm. long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these two marks is 20 cu. cm. The neck has a diameter of about 9 mm., and is graduated into tenths of cubic centimeters above the mark (*F*).

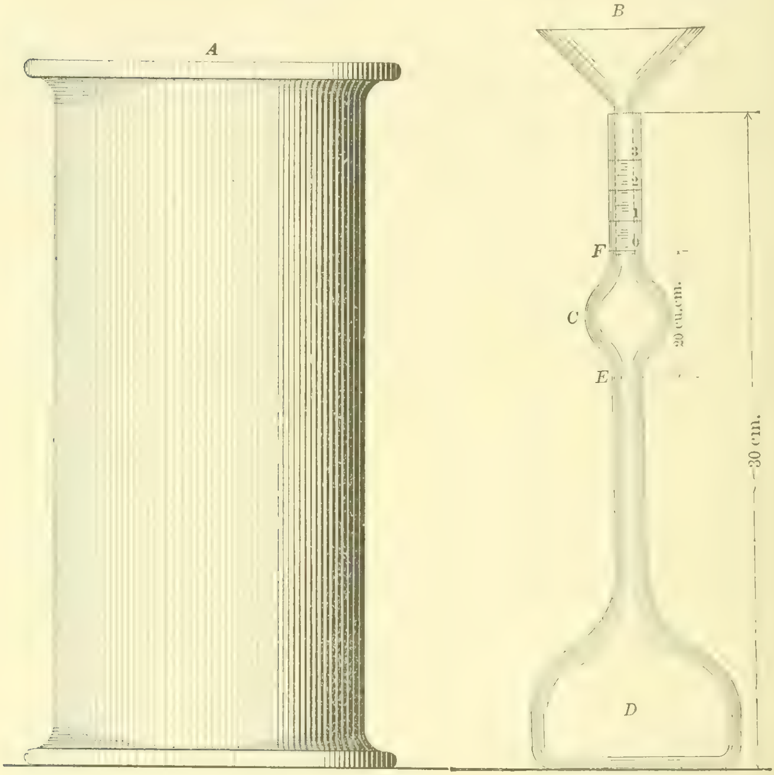
11.—Benzine (62° Beaumé naphtha) or kerosene free from water should be used in making the determination.

12.—*Method.*—The flask is filled with either of these liquids to the lower mark (*E*), and 64 grammes of cement, cooled to the temperature of the liquid, is slowly introduced through the funnel (*B*), (the stem of which should be long enough to extend into the flask to the top of the bulb (*C*)), taking care that the cement does not adhere to the sides of the flask, and that the funnel does not touch the liquid. After all the cement is introduced, the level of the liquid will rise to

some division of the graduated neck; this reading, plus 20 cu. cm., is the volume displaced by 64 grammes of the cement.

13.—The specific gravity is then obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement, in grammes,}}{\text{Displaced volume, in cubic centimeters.}}$$



LE CHATELIER S SPECIFIC GRAVITY APPARATUS.

FIG. 1.

14.—The flask, during the operation, is kept immersed in water in a jar (A), in order to avoid variations in the temperature of the liquid in the flask, which should not exceed ½° cent. The results of repeated tests should agree within 0.01. The determination of specific gravity should be made on the cement as received; if it should fall below 3.10, a second determination should be made after igniting the sample at a low red heat in the following manner: One-half gramme of cement is heated in a weighed platinum crucible, with cover, for 5 minutes

with a Bunsen burner (starting with a low flame and gradually increasing to its full height) and then heating for 15 minutes with a blast lamp; the difference between the weight after cooling and the original weight is the loss on ignition. The temperature should not exceed 900° cent., and the ignition should preferably be made in a muffle.

15.—The apparatus may be cleaned in the following manner: The flask is inverted and shaken vertically until the liquid flows freely and then held in a vertical position until empty; any traces of cement remaining can be removed by pouring into the flask a small quantity of clean liquid benzine or kerosene and repeating the operation.

Fineness.

16.—*Significance.*—It is generally accepted that the coarser particles in cement are practically inert, and it is only the extremely fine powder that possesses cementing qualities. The more finely cement is pulverized, other conditions being the same, the more sand it will carry and produce a mortar of a given strength.

17.—*Apparatus.*—The fineness of a sample of cement is determined by weighing the residue retained on certain sieves. Those known as No. 100 and No. 200, having approximately 100 and 200 wires per linear inch, respectively, should be used. They should be at least 8 in. in diameter. The wire cloth should be of brass wire, and should conform to the following requirements:

No. of sieve.	Diameter of wire.	Meshes per Linear Inch.	
		Warp.	Woof.
100	0.0042 to 0.0048 in.	95 to 101	93 to 103
200	0.0021 to 0.0023 "	192 to 203	190 to 205

The meshes in any smaller space, down to 0.25 in., should be proportional in number.

18.—*Method.*—The test should be made with 50 grammes of cement, dried at a temperature of 100° cent. (212° Fahr.).

19.—The cement is placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position and moved forward and backward about 200 times per minute, at the same time striking the side gently, on the up stroke, against the palm of the other hand. The operation is continued until not more than 0.05 gramme will pass through in one minute. The residue is weighed, then placed on the No. 100 sieve, and the operation repeated. The work may be expedited by placing in the sieve a few large steel shot, which should be removed before the final one minute of sieving. The sieves should be thoroughly dry and clean.

NORMAL CONSISTENCY.

20.—*Significance.*—The use of a proper percentage of water in making pastes* and mortars for the various tests is exceedingly important and affects vitally the results obtained.

21.—The amount of water, expressed in percentage by weight of the dry cement, required to produce a paste of plasticity desired, termed "normal consistency," should be determined with the Vicat apparatus in the following manner:

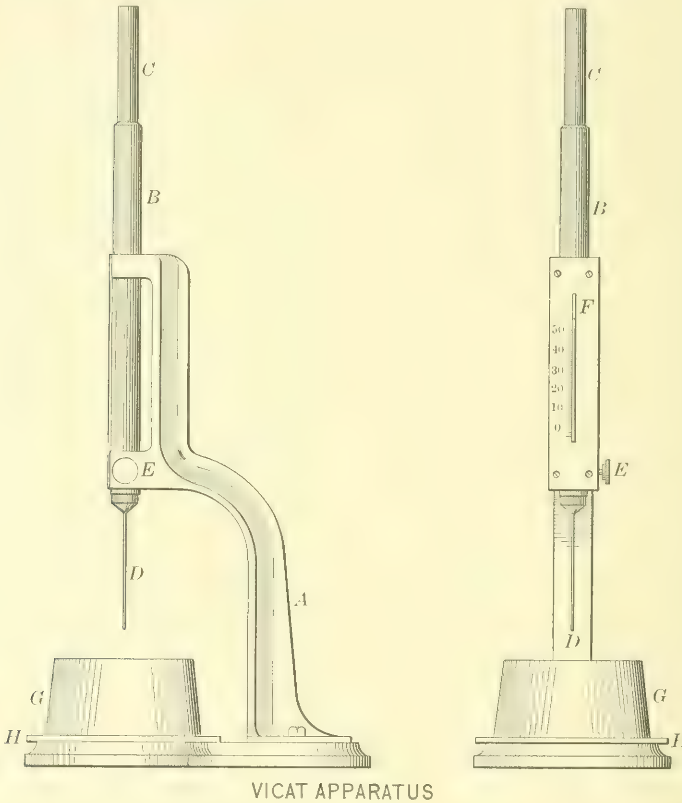


FIG. 2.

22.—*Apparatus.*—This consists of a frame (*A*), Fig. 2, bearing a movable rod (*B*), weighing 300 grammes, one end (*C*) being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle (*D*), 1 mm. in diameter, 6 cm. long. The rod is reversible,

*The term "paste" is used in this report to designate a mixture of cement and water, and the word "mortar" to designate a mixture of cement, sand, and water.

and can be held in any desired position by a screw (E), and has midway between the ends a mark (F) which moves under a scale (graduated to millimeters) attached to the frame (A). The paste is held by a conical, hard-rubber ring (G), 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate (H) about 10 cm. square.

23.—*Method.*—In making the determination, the same quantity of cement as will be used subsequently for each batch in making the test pieces, but not less than 500 grammes, with a measured quantity of water, is kneaded into a paste, as described in Paragraph 45, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand is pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end is then removed by a single movement of the palm of the hand; the ring is then placed on its larger end on a glass plate and the excess paste at the smaller end is sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care must be taken not to compress the paste. The paste confined in the ring, resting on the plate, is placed under the rod, the larger end of which is brought in contact with the surface of the paste; the scale is then read, and the rod quickly released.

24.—The paste is of normal consistency when the cylinder settles to a point 10 mm. below the original surface in one-half minute after being released. The apparatus must be free from all vibrations during the test.

25.—Trial pastes are made with varying percentages of water until the normal consistency is obtained.

26.—Having determined the percentage of water required to produce a paste of normal consistency, the percentage required for a mortar containing by weight one part of cement to three parts of standard Ottawa sand, is obtained from the following table, the amount being a percentage of the combined weight of the cement and sand.

PERCENTAGE OF WATER FOR STANDARD MORTARS.

Neat.	One cement, three standard Ottawa sand.	Neat.	One cement, three standard Ottawa sand.	Neat.	One cement, three standard Ottawa sand.
15	8.0	23	9.3	31	10.7
16	8.2	24	9.5	32	10.8
17	8.3	25	9.7	33	11.0
18	8.5	26	9.8	34	11.2
19	8.7	27	10.0	35	11.3
20	8.8	28	10.2	36	11.5
21	9.0	29	10.3	37	11.7
22	9.2	30	10.5	38	11.8

Time of Setting.

27.—*Significance.*—The object of this test is to determine the time which elapses from the moment water is added until the paste ceases to be plastic (called the "initial set"), and also the time until it acquires a certain degree of hardness (called the "final set" or "hard set"). The former is the more important, since, with the commencement of setting, the process of crystallization begins. As a disturbance of this process may produce a loss of strength, it is desirable to complete the operation of mixing or moulding or incorporating the mortar into the work before the cement begins to set.

28.—*Apparatus.*—The initial and final set should be determined with the Vicat apparatus described in Paragraph 22.

29.—*Method.*—A paste of normal consistency is moulded in the hard-rubber ring, as described in Paragraph 23, and placed under the rod (B), the smaller end of which is then carefully brought in contact with the surface of the paste, and the rod quickly released.

30.—The initial set is said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate; and the final set, when the needle does not sink visibly into the paste.

31.—The test pieces should be kept in moist air during the test; this may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth; the cloth to be kept from contact with them by means of a wire screen; or they may be stored in a moist box or closet.

32.—Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration.

33.—The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is, therefore, only approximate.

Standard Sand.

34.—The sand to be used should be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve, and retained on a No. 30 sieve. The sieves should be at least 8 in. in diameter; the wire cloth should be of brass wire and should conform to the following requirements:

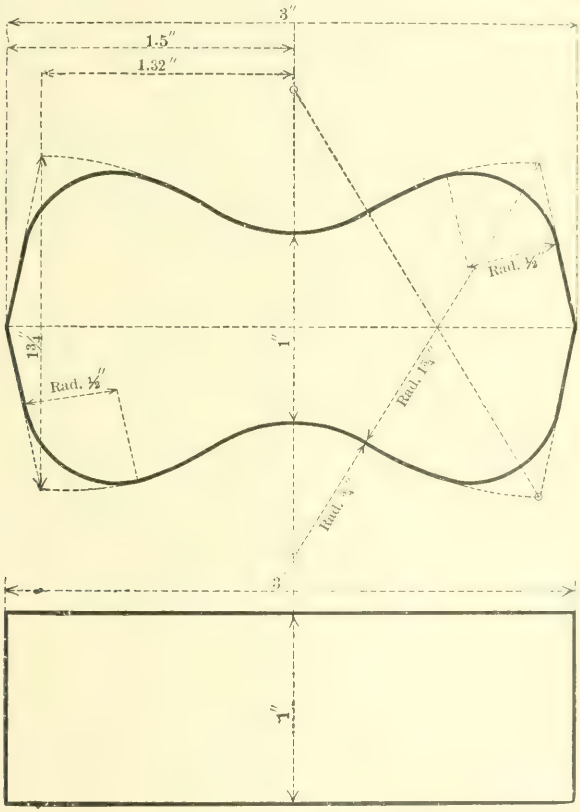
No. of sieve.	Diameter of wire.	Meshes per Linear Inch.	
		Warp.	Woof.
20	0.016 to 0.017 in.	19.5 to 20.5	19 to 21
30	0.011 to 0.012 "	29.5 to 30.5	28.5 to 31.5

Sand which has passed the No. 20 sieve is standard when not more than 5 grammes passes the No. 30 sieve in one minute of continuous sifting of a 500-gramme sample.*

Form of Test Pieces.

35.—For tensile tests the form of test piece shown in Fig. 3 should be used.

36.—For compressive tests, 2-in. cubes should be used.



DETAILS FOR BRIQUETTE.

Fig. 3.

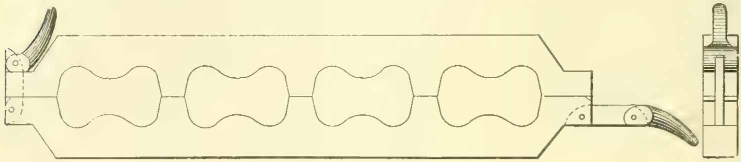
Moulds.

37.—The moulds should be of brass, bronze, or other non-corrodible material, and should have sufficient metal in the sides to prevent spreading during moulding.

* This sand may now (1912) be obtained from the Ottawa Silica Co., at a cost of two cents per pound, f. o. b. cars, Ottawa, Ill.

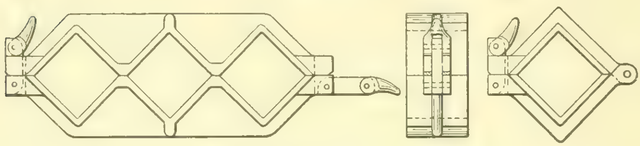
38.—Moulds may be either single or gang moulds. The latter are preferred by many. If used, the types shown in Figs. 4 and 5 are recommended.

39.—The moulds should be wiped with an oily cloth before using.



DETAILS FOR GANG MOULD.

FIG. 4.



MOULD FOR COMPRESSION TEST PIECES

FIG. 5.

MIXING.

40.—The proportions of sand and cement should be stated by weight; the quantity of water should be stated as a percentage by weight of the dry material.

41.—The metric system is recommended because of the convenient relation of the gramme and the cubic centimeter.

42.—The temperature of the room and of the mixing water should be maintained as nearly as practicable at 21° cent. (70° Fahr.).

43.—The quantity of material to be mixed at one time depends on the number of test pieces to be made; 1 000 grammes is a convenient quantity to mix by hand methods.

44.—The Committee has investigated the various mechanical mixing machines thus far devised, but cannot recommend any of them, for the following reasons: (1) the tendency of most cement is to "ball up" in the machine, thereby preventing working it into a homogeneous paste; (2) there are no means of ascertaining when the mixing is complete without stopping the machine; and (3) it is difficult to keep the machine clean.

45.—*Method.*—The material is weighed, placed on a non-absorbent surface (preferably plate glass), thoroughly mixed dry if sand be used, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the center by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for one minute. During the operation the hands should be protected by rubber gloves.

Moulding.

46.—The Committee has not been able to secure satisfactory results with existing moulding machines; the operation of machine moulding is very slow; and is not practicable with pastes or mortars containing as large percentages of water as herein recommended.

47.—*Method.*—Immediately after mixing, the paste or mortar is placed in the moulds with the hands, pressed in firmly with the fingers, and smoothed off with a trowel without ramming. The material should be heaped above the mould, and, in smoothing off, the trowel should be drawn over the mould in such a manner as to exert a moderate pressure on the material. The mould should then be turned over and the operation of heaping and smoothing off repeated.

48.—A check on the uniformity of mixing and moulding may be afforded by weighing the test pieces on removal from the moist closet; test pieces from any sample which vary in weight more than 3% from the average should not be considered.

Storage of the Test Pieces.

49.—During the first 24 hours after moulding, the test pieces should be kept in moist air to prevent drying.

50.—Two methods are in common use to prevent drying: (1) covering the test pieces with a damp cloth, and (2) placing them in a moist closet. The use of the damp cloth, as usually carried out, is objectionable, because the cloth may dry out unequally and in consequence the test pieces will not all be subjected to the same degree of moisture. This defect may be remedied to some extent by immersing the edges of the cloth in water; contact between the cloth and the test pieces should be prevented by means of a wire screen, or some similar arrangement. A moist closet is so much more effective in securing uniformly moist air, and is so easily devised and so inexpensive, that the use of the damp cloth should be abandoned.

51.—A moist closet consists of a soapstone or slate box, or a wooden box lined with metal, the interior surface being covered with felt or broad wicking kept wet, the bottom of the box being kept covered with water. The interior of the box is provided with glass shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

52.—After 24 hours in moist air, the pieces to be tested after longer periods should be immersed in water in storage tanks or pans made of non-corrodible material.

53.—The air and water in the moist closet and the water in the storage tanks should be maintained as nearly as practicable at 21° cent. (70° Fahr.).

Tensile Strength.

54.—The tests may be made with any standard machine.

55.—The clip is shown in Fig. 6. It must be made accurately, the pins and rollers turned, and the rollers bored slightly larger than the pins so as to turn easily. There should be a slight clearance at each end of the roller, and the pins should be kept properly lubricated and free from grit. The clips should be used without cushioning at the points of contact.

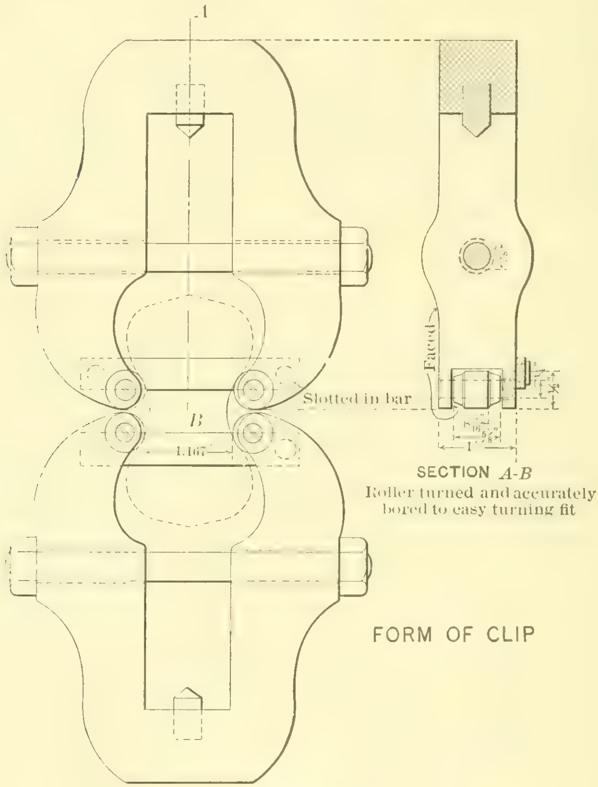


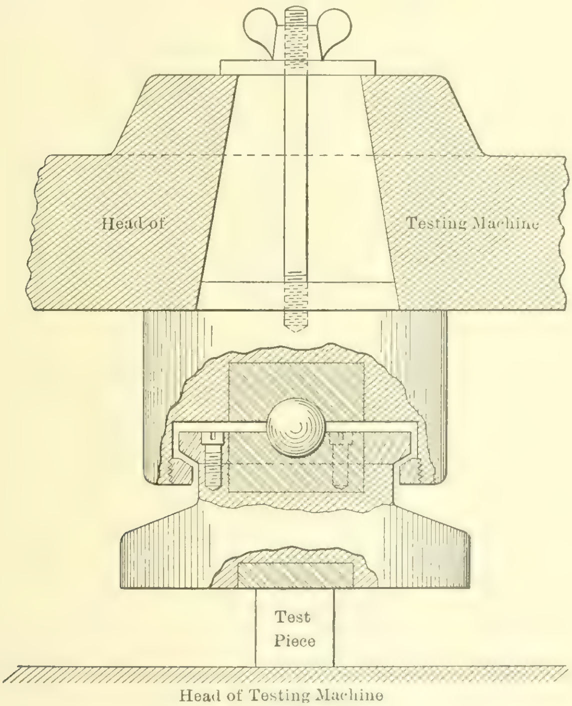
Fig. 6.

56.—Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the test pieces in the testing machine, as cross strains, produced by imperfect centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often causes the test piece to break before the ultimate strength is reached. The bearing surfaces of the clips and test pieces must be

kept free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lb. per min. The average of the results of the test pieces from each sample should be taken as the test of the sample. Test pieces which do not break within $\frac{1}{4}$ in. of the center, or are otherwise manifestly faulty, should be excluded in determining average results.

Compressive Strength.

57.—The tests may be made with any machine provided with means for so applying the load that the line of pressure is along the axis of the test piece. A ball-bearing block for this purpose is shown in Fig. 7. Some appliance should be provided to facilitate placing the axis of the test piece exactly in line with the center of the ball-bearing.

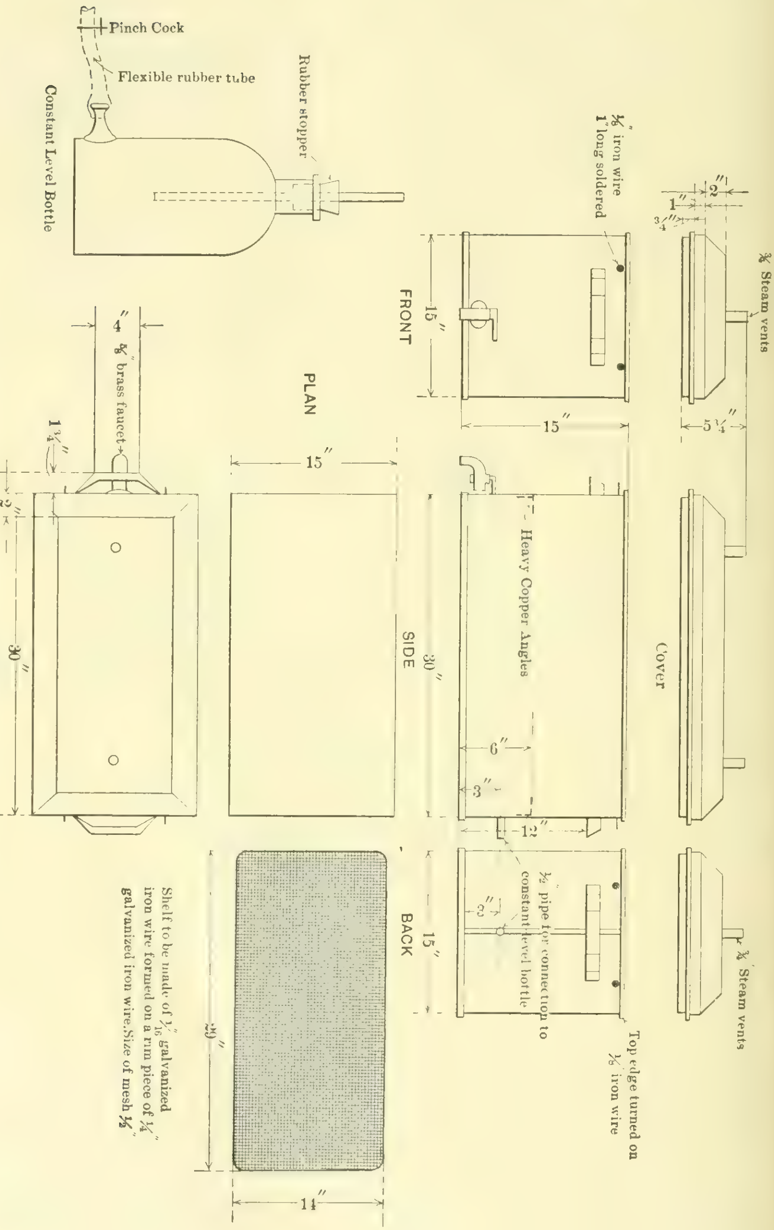


BALL-BEARING BLOCK FOR TESTING MACHINE

Fig. 7.

58.—The test piece should be placed in the testing machine, with a piece of heavy blotting paper on each of the crushing faces, which should be those that were in contact with the mould.

APPARATUS FOR MAKING ACCELERATED TEST FOR SOUNDNESS OF CEMENT.



To be made of sheet copper weighing 22 oz. per sq. ft., tinned inside.
All seams to be lapped where possible. Hard solder only to be used

FIG. 8.

CONSTANCY OF VOLUME.

59.—*Significance.*—The object is to detect those qualities which tend to destroy the strength and durability of a cement. Under normal conditions these defects will in some cases develop quickly, and in other cases may not develop for a considerable time. Since the detection of these destructive qualities before using the cement in construction is essential, tests are made not only under normal conditions but under artificial conditions created to hasten the development of these defects. Tests may, therefore, be divided into two classes: (1) Normal tests, made in either air or water maintained, as nearly as practicable, at 21° cent. (70° Fahr.); and (2) Accelerated tests, made in air, steam or water, at temperature of 45° cent. (113° Fahr.) and upward. The Committee recommends that these tests be made in the following manner:

60.—*Methods.*—Pats, about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, should be made on clean glass plates (about 4 in. square) from cement paste of normal consistency, and stored in a moist closet for 24 hours.

61.—*Normal Tests.*—After 24 hours in the moist closet, a pat is immersed in water for 28 days and observed at intervals. A similar pat, after 24 hours in the moist closet, is exposed to the air for 28 days or more and observed at intervals.

62.—*Accelerated Test.*—After 24 hours in the moist closet, a pat is placed in an atmosphere of steam, upon a wire screen 1 in. above boiling water, for 5 hours. The apparatus should be so constructed that the steam will escape freely and atmospheric pressure be maintained. Since the type of apparatus used has a great influence on the results, the arrangement shown in Fig. 8 is recommended.

63.—Pats which remain firm and hard and show no signs of cracking, distortion, or disintegration are said to be "of constant volume" or "sound."

64.—Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

65.—In the present state of our knowledge it cannot be said that a cement which fails to pass the accelerated test will prove defective in the work; nor can a cement be considered entirely safe simply because it has passed these tests.

GEORGE S. WEBSTER, *Chairman.*
RICHARD L. HUMPHREY, *Secretary.*
W. B. W. HOWE,
F. H. LEWIS,
S. B. NEWBERRY,
ALFRED NOBLE,
CLIFFORD RICHARDSON,
L. C. SABIN,
GEORGE F. SWAIN.

METHODS FOR TESTING CEMENT.*
CONDENSED FOR USE IN SPECIFICATIONS.

1. *Sampling.*

Cement in barrels shall be sampled through a hole made in the head, or in one of the staves midway between the heads, by means of an auger or a sampling iron similar to that used by sugar inspectors; if in bags, the sample shall be taken from surface to center. Cement in bins shall be sampled in such a manner as to represent fairly the contents of the bin. The number of samples taken shall be as directed by the Engineer, who will determine whether the samples shall be tested separately or mixed.

The samples shall be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material.

2. *Chemical Analysis.*

The method to be followed shall be that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, reported in the *Journal* of the Society for Chemical Industry, Vol. 21, p. 12, 1902, and published in *Engineering News,* Vol. 50, p. 60, 1903, and in *Engineering Record,* Vol. 48, p. 49, 1903, and in addition thereto the following:

The insoluble residue shall be determined as follows: To a 1-gramme sample of the cement shall be added 30 cu. cm. of water and 10 cu. cm. of concentrated hydrochloric acid, and then warmed until the effervescence ceases, and digested on a steam bath until dissolved. The residue is filtered, washed with hot water, and the filter paper and contents digested on the steam bath in a 5% solution of sodium carbonate. This residue is filtered, washed with hot water, then with hot hydrochloric acid, and finally with hot water, and then ignited at a red heat and weighed. The quantity so obtained is the insoluble residue.

3. *Specific Gravity.*

The determination of specific gravity shall be made with a standardized Le Chatelier apparatus. This consists of a flask (*D*), Fig. 1, page 114, of about 120 cu. cm. capacity, the neck of which is about 20 cm. long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these two marks is 20 cu. cm. The neck has a diameter of about 9 mm., and is graduated into tenths of cubic centimeters above the mark (*F*).

Benzine (62° Beaumé naphtha) or kerosene free from water shall be used in making the determination. The flask is filled with either

---

*Accompanying Final Report of Special Committee on Uniform Tests of Cement. dated, January 17th, 1912.

of these liquids to the lower mark (E) and 64 grammes of cement, cooled to the temperature of the liquid, is slowly introduced through the funnel (B), (the stem of which should be long enough to extend into the flask to the top of the bulb (C)), taking care that the cement does not adhere to the sides of the flask, and that the funnel does not touch the liquid. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; this reading, plus 20 cu. cm., is the volume displaced by 64 grammes of the cement. The specific gravity is obtained from the formula,

$$\text{Specific gravity} = \frac{\text{Weight of cement, in grammes,}}{\text{Displaced volume, in cubic centimeters.}}$$

The flask, during the operation, is kept immersed in water in a jar (A), in order to avoid variations in the temperature of the liquid in the flask, which should not exceed $\frac{1}{2}°$ cent. The results of repeated tests should agree within 0.01.

The determination of specific gravity shall be made on the cement as received; if it should fall below 3.10, a second determination shall be made after igniting the sample at a low red heat. The ignition shall be carried out in the following manner:

One-half gramme of cement is heated in a weighed platinum crucible, with cover, for 5 minutes with a Bunsen burner (starting with a low flame and gradually increasing to its full height) and then heated for 15 minutes with a blast lamp; the difference between the weight after cooling and the original weight is the loss on ignition. The temperature should not exceed 900° cent., and the ignition should preferably be made in a muffle.

4. *Fineness.*

The fineness shall be determined by weighing the residue retained on No. 100 and No. 200 sieves. The sieves shall be of brass wire, and shall conform to the following requirements:

No. of sieve.	Diameter of wire.	Meshes, per Linear Inch.	
		Warp.	Woof.
100	0.0042 to 0.0048 in.	95 to 101	93 to 103
200	0.0021 to 0.0023 "	192 to 203	190 to 205

The meshes in any smaller space, down to 0.25 in., shall be proportional in number.

Fifty grammes of cement, dried at a temperature of 100° cent. (212° Fahr.), shall be placed on the No. 200 sieve, which, with pan

and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward about 200 times per minute, at the same time striking the side gently, on the up stroke, against the palm of the other hand. The operation is continued until not more than 0.05 gramme will pass through in one minute. The residue is weighed, then placed on the No. 100 sieve, and the operation repeated. The work may be expedited by placing in the sieve a few large steel shot, which should be removed before the final one minute of sieving. The sieves should be thoroughly dry and clean.

5. *Normal Consistency.*

The amount of water, expressed in percentage by weight of the dry cement, required to produce a paste* of the plasticity desired, termed "normal consistency," shall be determined with the Vicat apparatus:

This consists of a frame (*A*), Fig. 2, page 116, bearing a movable rod (*B*), weighing 300 grammes, one end (*C*) being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle (*D*), 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw (*E*), and has midway between the ends a mark (*F*) which moves under a scale (graduated to millimeters) attached to the frame (*A*). The paste is held in a conical, hard-rubber ring (*G*), 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate (*H*) about 10 cm. square.

In making the determination of normal consistency, the same quantity of cement as will be used subsequently for each batch in making the test pieces, but not less than 500 grammes, together with a measured amount of water, is kneaded into a paste, as described in Section 9, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand is pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end is then removed by a single movement of the palm of the hand; the ring is then placed on its larger end on a glass plate and the excess paste at the smaller end is sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care must be taken not to compress the paste. The paste confined in the ring, resting on the plate, is placed under the rod, the larger end of which is carefully brought in contact with the surface of the paste; the scale is then read, and the rod quickly released.

The paste is of normal consistency when the cylinder settles to a point 10 mm. below the original surface in one-half minute after being

* The term "paste" is used in these specifications to designate a mixture of cement and water, and the word "mortar" to designate a mixture of cement, sand, and water.

released. The apparatus must be free from all vibrations during the test.

Trial pastes are made with varying percentages of water until the normal consistency is attained.

Having determined the percentage of water required to produce a paste of a normal consistency, the percentage required for a mortar containing, by weight, one part of cement to three parts of standard Ottawa sand, shall be obtained from the following table, the amount being a percentage of the combined weight of the cement and sand.

PERCENTAGE OF WATER FOR STANDARD MORTARS.

Neat.	One cement, three standard Ottawa sand.	Neat.	One cement, three standard Ottawa sand.	Neat.	One cement, three standard Ottawa sand.
15	8.0	23	9.3	31	10.7
16	8.2	24	9.5	32	10.8
17	8.3	25	9.7	33	11.0
18	8.5	26	9.8	34	11.2
19	8.7	27	10.0	35	11.3
20	8.8	28	10.2	36	11.5
21	9.0	29	10.3	37	11.7
22	9.2	30	10.5	38	11.8

6. *Time of Setting.*

The time of setting shall be determined with the Vicat apparatus in the following manner:

A paste of normal consistency is moulded in the hard-rubber ring, as described in Section 5, and placed under the rod (B), the smaller end of which is then carefully brought in contact with the surface of the paste, and the rod quickly released.

The cement is considered to have acquired its initial set when the needle ceases to pass a point 5 mm. above the glass plate; and the final set, when the needle does not sink visibly into the paste.

The test pieces must be kept in moist air during the test.

7. *Standard Sand.*

The sand shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve, and retained on a No. 30 sieve.

The sieves shall be at least 8 in. in diameter, and the wire cloth shall be of brass wire and shall conform to the following requirements:

No. of sieve.	Diameter of wire.	MESHES, PER LINEAR INCH.	
		Warp.	Woof.
20	0.016 to 0.017 in.	19.5 to 20.5	19 to 21
30	0.011 to 0.012 "	29.5 to 30.5	28.5 to 31.5

Sand which has passed the No. 20 sieve is standard when not more than 5 grammes passes the No. 30 sieve in one minute of continuous sifting of a 500-gramme sample.*

8. *Form of Test Pieces.*

For tensile tests the form of test pieces shown in Fig. 3 shall be used.

For compressive tests, 2-in. cubes shall be used.

9. *Mixing and Moulding.*

The material shall be weighed, placed on a non-absorbent surface, thoroughly mixed dry if sand be used, and a crater formed in the center into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the center by the aid of a trowel. As soon as the water has been absorbed, the operation of mixing shall be completed by vigorously kneading with the hands for one minute.

Immediately after mixing, the paste or mortar shall be placed in the mould (Figs. 4 and 5, page 120) with the hands, pressed in firmly with the fingers, and smoothed off with a trowel without ramming. The material shall be heaped above the mould, and, in smoothing off, the trowel shall be drawn over the mould in such a manner as to exert a moderate pressure on the material; the mould shall then be turned over and the operation of heaping and smoothing off repeated.

The temperature of the room and of the mixing water shall be maintained as nearly as practicable at 21° cent. (70° Fahr.).

10. *Storage of the Test Pieces.*

During the first 24 hours after moulding, the test pieces shall be stored in a moist closet. This consists of a box of soapstone or slate, or of wood lined with metal, the interior surface being covered with felt or broad wicking kept wet, the bottom of the box being kept covered with water. The interior of the box is provided with glass shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

Test pieces from any sample which vary more than 3% in weight from the average, after removal from the moist closet, shall not be considered in determining strength.

After 24 hours in the moist closet, the pieces to be tested after longer periods shall be immersed in water in storage tanks or pans made of non-corrodible material.

---

*This sand may now (1912) be obtained from the Ottawa Silica Co., at a cost of two cents per pound, f. o. b. cars, Ottawa, Ill.

The air and water in the moist closet and the water in the storage tanks shall be maintained, as nearly as practicable, at 21° cent. (70° Fahr.).

11. *Tests of Tensile Strength.*

The tests may be made with any standard machine.

The clip is shown in Fig. 6, page 122. It must be made accurately, the pins and rollers turned, and the rollers bored slightly larger than the pins so as to turn easily. There should be a slight clearance at each end of the roller, and the pins should be kept properly lubricated and free from grit. The clips shall be used without cushioning at the points of contact.

The test pieces shall be broken as soon as they are removed from the water. The load shall be applied at the rate of 600 lb. per minute.

Test pieces which do not break within ¼ in. of the center, or are otherwise manifestly faulty, shall be excluded in determining average results.

12. *Tests of Compressive Strength.*

The tests may be made with any machine provided with means for so applying the load that the line of pressure is along the axis of the test piece. A ball-bearing block for this purpose is shown in Fig. 7, page 123.

The test pieces as soon as they are removed from the water shall be placed in the testing machine, with a piece of heavy blotting paper on each of the crushing faces, which should be those that were in contact with the mould.

13. *Constancy of Volume.*

The tests for constancy of volume comprise "normal tests," which are made in air or water maintained as nearly as practicable at 21° cent. (70° Fahr.), and the "accelerated test," which is made in steam. These tests shall be made in the following manner:

Pats about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square, from cement paste of normal consistency, and stored in a moist closet for 24 hours.

Normal Tests.—After 24 hours in the moist closet, a pat is immersed in water and observed at intervals. A similar pat after 24 hours in the moist closet is exposed to the air for 28 days or more and observed at intervals. The air and water are maintained as nearly as practicable at 21° cent. (70° Fahr.).

Accelerated Test.—After 24 hours in the moist closet, a pat is placed in an atmosphere of steam, upon a wire screen 1 in. above boiling water, for 5 hours, the apparatus being such that the steam will

escape freely and atmospheric pressure be maintained. The apparatus is shown in Fig. 8, page 124.

The cement passes these tests when the pats remain firm and hard, with no signs of cracking, distortion, or disintegration.

George S. Webster, *Chairman.*
Richard L. Humphrey, *Secretary.*
W. B. W. Howe,
F. H. Lewis,
S. B. Newberry,
Alfred Noble,
Clifford Richardson,
L. C. Sabin,
George F. Swain.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

March 6th, 1912.—8.30 P. M.—This will be a regular business meeting. A paper by N. B. Sweitzer, Assoc. M. Am. Soc. C. E., entitled "Retracement-Resurveys—Court Decisions and Field Procedure," will be presented for discussion.

This paper was printed in *Proceedings* for January, 1912.

March 20th, 1912.—8.30 P. M.—At this meeting a paper by Charles B. Buerger, Assoc. M. Am. Soc. C. E., entitled "Rebuilding Three Large Pumping Engines," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

CHANGES IN METHOD OF PUBLISHING TRANSACTIONS

The *Transactions*, which during the past three years have been issued in four volumes per year, will in 1912 and thereafter be published in one annual volume.

This important change has been decided on by the Board of Direction because it will overcome, or mitigate to a considerable extent, the many disadvantages connected with the old system, as detailed in the report of the Secretary to the Board dated June 6th, 1911 (*Proceedings* for August, 1911, p. 319).

The yearly volumes will be printed on thin "India" or "Bible" paper, and will contain approximately as much material as four of the volumes hitherto published. Its thickness will be somewhat less than half that of the four volumes combined.

To non-members the subscription for this single volume, if entered before February 1st, will be the same as heretofore for the four volumes: $12, with a discount to libraries, book dealers, etc., of 25 per cent.

To members the cost of binding will be $1.50 per volume for half morocco and 75 cents for cloth, thus effecting a saving of from $1.25 to $2.50 per annum to each member who has his *Transactions* bound.

It is expected that the volume for 1912 (Vol. LXXV) will be issued toward the close of the year.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many

searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society, in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

*Proceedings, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Gavin N. Houston, M. Am. Soc. C. E., 409 Equitable Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

January 13th, 1912.—The meeting was called to order; President Anderson in the chair; G. N. Houston, Secretary; and present, also, 13 members and 4 guests.

The minutes of the December meeting were read and approved.

A paper on "The Larimer-Poudre Tunnel," was presented by Burgis G. Coy, Assoc. M. Am. Soc. C. E., who illustrated his remarks with lantern slides, and a general discussion of the subject followed.

Adjourned.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all Meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten=Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur= und Architekten=Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From January 5th to February 9th, 1912)

DONATIONS *

A TEXT-BOOK ON ROOFS AND BRIDGES.

Part III, Bridge Design. By Mansfield Merriman, M. Am. Soc. C. E., and Henry S. Jacoby, Assoc. Am. Soc. C. E. Fifth Edition, Partly Rewritten. Cloth, $9\frac{1}{4}$ x 6 in., illus., 8 + 413 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1912 $2.50.

In the preface to the present edition it is stated that the subject is presented "both rationally, as an application of the principle of mechanics, and practically, as an illustration of modern economic construction." It is further stated that the subject-matter has been thoroughly revised and partly rewritten in order to bring the book up to date, it being the constant aim of the authors not only to give the latest details of modern bridge practice, but also to set forth the reasons for such practice in a manner adapted to the needs of the student and young engineers. As more than 90% of all bridges are stated to be those resting on two supports, this volume is confined to that class. Chapter X is entirely new matter and is said to represent recent developments in highway bridge construction in the Middle West. There are also new plates, and the references to engineering literature at the ends of the chapters are stated to have been considerably extended. The Contents are: History and Literature; Principles of Economic Design; Bridge Contracts and Office Work; Fabrication and Erection; Tables and Standards; Details of Plate-Girder Bridges; Design of a Plate-Girder Bridge; Details of Railroad Pin Bridges; Design of a Pin Truss Bridge; Highway Bridges; Railroad Riveted Bridges; Index.

SEWAGE SLUDGE.

Treatment and Utilization of Sludge, by Alexander Elsner; The Drying of Sludge, by Fr. Spillner, Translated by Kenneth and Rose S. Allen; Operation of Mechanical Sewage Plants, by Fr. Spillner and Mr. Blunk, Translated by Emil Kuichling, M. Am. Soc. C. E.; Sludge Treatment in the United States, by Kenneth Allen, M. Am. Soc. C. E. Cloth, $9\frac{1}{2}$ x $6\frac{1}{2}$ in., illus., 74 + 272 pp. New York and London, McGraw-Hill Book Company, 1912. $2.50.

The monographs on sludge, by Dr. Elsner, Dr. Spillner and Mr. Blunk, and Mr. Allen, contained in this book, will, it is stated, be welcomed by those interested in the subject. Part I, Dr. Elsner's paper, is stated to be a general discussion of the requirements necessary for the treatment and utilization of sludge, and their realization by existing methods. It is stated to be based on personal inspection of a number of important German and English plants, on a study of the most recent literature on the subject, and on data furnished by city officials. Part II, Dr. Spillner's paper on "The Drying of Sludge" is stated to be particularly valuable on account of the detailed results obtained, up to the end of 1909, in the operation of the plants at Emschergenossenschaft, and as chemist, the author gives this information at first hand. Part III, the paper on the operation of mechanical sewage plants by Dr. Spillner and Mr. Blunk, relates to experiences derived from the operation of tanks of the Emscher and Imhoff types, and is stated to contain comments and criticisms on their operation and efficiency. Part IV, Mr. Allen's paper, relates to the characteristics of American sewages and to the more important results reached in the United States in the treatment and utilization of sludge. The measures given are those used by American engineers, but the metric measures used by the German authors are also stated. Lists of localities mentioned and author references are given, as well as a general index.

GEODETIC SURVEYING

And the Adjustment of Observations (Method of Least Squares). By Edward L. Ingram, Assoc. M. Am. Soc. C. E. Cloth, $9\frac{1}{2}$ x $6\frac{1}{2}$ in., illus., 20 + 389 pp. New York and London, McGraw-Hill Book Company, 1911. $3.00.

This volume, it is stated, has been prepared to meet the apparent need of a textbook containing the fundamental principles of geodetic surveying and the ad-

* Unless otherwise specified, books in this list have been donated by the publisher.

justment of observations as they should be taught to students of civil engineering. No attempt has been made to treat the subject exhaustively, the object being rather to build up a book containing everything desirable for a student or useful to the practicing engineer. The subject-matter is divided into two parts, each being complete in itself. The first contains a complete treatment of geodetic methods and rules for making the necessary adjustments, and includes a study of geodetic work without entering into involved mathematics. The second part includes the fundamental principles of least squares and the mathematical theory on which rules for adjusting observations are based. It is intended that engineering students shall take the two parts in succession. A large number of illustrative examples are given, which are worked out in detail, so that every process may be thoroughly understood. The Contents are: Introduction; Part I, Geodetic Surveying: Principles of Triangulation; Base-Line Measurement; Measurement of Angles; Triangulation Adjustments and Computations; Computing the Geodetic Positions; Geodetic Leveling; Astronomical Determinations; Geodetic Map Drawing. Part II, Adjustment of Observations by the Method of Least Squares: Definitions and Principles; The Theory of Errors; Most Probable Values of Independent Quantities; Most Probable Values of Conditioned and Computed Quantities; Probable Errors of Observed and Computed Quantities; Application to Angular Measurements; Application to Base-Line Work; Application to Level Work; Plates; Tables; Bibliography; Index.

STRENGTH OF MATERIALS.

By James E. Boyd. Cloth, 9½ x 6½ in., illus., 12 + 295 pp. New York and London, McGraw-Hill Book Company, 1911. $2.50.

The preface states that this book is intended to aid the student to grasp the physical and mathematical ideas underlying the mechanics of materials, and that sufficient experimental facts and simple applications are included to sustain his interest, fix his theory, and prepare him for the technical subjects discussed in works on machine design, reinforced concrete, or stresses in structures. The author assumes that the reader has completed the Integral Calculus and has taken a course in Theoretical Mechanics which includes statics and the moment of inertia of plane areas. Problems are given with nearly every article, the first of each set usually requiring the use of the principle given in the preceding text, and the later ones aiming to combine this principle with others previously studied and with the fundamental operations of mathematics and mechanics. The author states that this book is designed for use with "Cambria Steel," to which references are made, and that it is adapted for use with any edition of the Handbook. The Contents are: Notation; Stresses; Stress Beyond the Elastic Limit; Shear; Riveted Joints; Beams; Stresses in Beams; Deflection of Beams; Beams with More than Two Supports; Shear in Beams; Beams of Special Form; Bending Combined with Tension or Compression; Columns; Column Formulas Used by Engineers; Torsion; Resilience in Bending and Torsion; Center of Gravity; Moment of Inertia; Computation without Integrals; Repeated Stresses; Index.

DYNAMICS OF MACHINERY.

By Gaetano Lanza. Cloth, 9¼ x 6 in., illus., 5 + 246 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1911. $2.50.

After treating of the principal types of dynamomenters in his first chapter, the author, as stated in the preface, devotes the remainder of this book to bringing together, in one volume, the methods of dealing with the inertia forces which arise in various kinds of machinery, especially in cases where high speeds are used. Among the examples of such machinery which he gives are high-speed steam engines (including high-speed locomotives), and gas engines, in which he states careful consideration must be given to the action of the reciprocating parts; the inertia governor, pulleys, flywheels, steam turbines, dynamo armatures, centrifugal machines; hydroextractors, etc.; and machinery in which the gyroscope is used in engineering, namely, in the steering of torpedoes, the steadying of vessels at sea, the Brennan monorail car, the gyroscopic compass, etc. The Contents are: Dynamometers; Moments and Products of Inertia; Action of Reciprocating Parts; Governors; Bodies Having a High Rotative Speed; Appendix to Chapter II (A); Appendix to Chapter IV (B); Appendix to Chapter V (C); Index.

Gifts have also been received from the following:

Alexandra (Newport and South Wales) Docks & Ry. Co. 1 pam.
Alvord, John W. 1 pam.
Am. Electrochemical Soc. 1 vol.
Am. Inst. of Elec. Engrs. 1 bound vol.
Am. Mathematical Soc. 1 pam.
Am. Min. Congress. 1 vol.
Am. Soc. of Agri. Engrs. 1 vol.
Anthony, Charles. 1 pam.
Arnold, Bion J. 1 vol.

Binghamton, N. Y.-Water Commrs. 1 pam.
Bombay, India-Dept. of Public Works. 1 pam.
Cambria Steel Co. 1 bound vol.
Cambridge Univ. & Town Water-Works Co. 1 pam.
Canada-Dept. of Marine and Fisheries. 1 vol.
Case School of Applied Sci. 1 vol.
Congreso Cientifico, 4th, Santiago de Chile. 1 vol.
Connecticut-State Board of Health. 4 bound vol.
Dartmouth Coll. 1 vol.
Detroit, Mich.-Board of Water Commrs. 1 pam.
Eiffel, G. 1 vol.
Emerson Co., The. 1 pam.
France-Ministère des Travaux Publics. 3 pam.
Fritz, John. 1 bound vol.
Great Britain-Patent Office. 5 vol.
Great Eastern Ry. Co. 1 pam.
Great Northern & City Ry. Co. 1 pam.
Greiner, J. E. 3 pam.
Harrisburg, Pa.-Board of Commrs. of Water and Lighting Dept. 1 pam.
Harvard Univ. 1 bound vol.
Idaho-State Engr. 1 vol.
Idaho-State Insp. of Mines. 1 pam.
Illinois-State Geol. Survey. 1 pam.
Illinois-State Min. Board. 1 bound vol.
Illinois, Univ. of-Agri. Exper. Station. 2 pam.
Institution of Civ. Engrs. 1 bound vol., 2 vol.
Institution of Engrs. and Shipbuilders in Scotland. 1 bound vol.
Institution of Municipal and County Engrs. 1 bound vol., 1 vol.
Iron and Steel Inst. 1 bound vol.
Kiersted, Wynkoop. 1 pam.
Kimball, George A. 1 pam.
Lederle & Provost. 1 pam.
London, Brighton & South Coast Ry. Co. 1 pam.
London Elec. Ry. Co. 1 pam.
London, Tilbury & Southend Ry. Co. 1 pam.
Madeley, J. W. 1 bound vol.
Manchester, England-Cleansing Dept. 1 pam.
Maryland-Public Service Comm. 2 bound vol.
Massachusetts-Board of Harbor and Land Commrs. 1 bound vol.
Massachusetts-State Board of Health. 1 bound vol.
Master Car Builders' Assoc. 1 bound vol.
Maury, Dabney H. 1 pam.
Met. Ry. Co. 1 pam.
Mexican Southern Ry. Co., Ltd. 1 pam.
Michigan-Geol. Survey. 2 bound vol.
Michigan-State Highway Dept. 1 pam.
Milwaukee, Wis.-Bureau of Economy and Efficiency. 2 pam.
National Assoc. of Cement Users. 1 bound vol.
New Jersey-Board of Equalization of Taxes. 1 vol.
New Jersey-Geol. Survey. 2 bound vol., 2 pam.
New York City-Dept. of Health. 1 bound vol.
New York State-Attorney-Gen. 2 bound vol.
New York State-Public Service Comm., First Dist. 7 pam.
New York-State Engr. and Surv. 1 bound vol., 1 pam.
New York Univ. 1 vol., 1 pam.
Oklahoma-Dept. of Mines, Oil and Gas. 1 vol.
Oregon-State Forester. 2 pam.
Panama R. R. Co. 1 vol.
Philippine Islands-Bureau of Health. 1 vol.
Providence, R. I.-Dept. of Public Works. 1 pam.
Rhode Island-State Board of Health. 1 bound vol.
Royal Inst. of British Archts. 1 bound vol.
Royal Philosophical Soc. of Glasgow. 1 vol.
Smith, Earl B. 1 pam.
Smithsonian Institution. 1 bound vol.
South African Rys. 1 vol.
South Eastern Ry. Co. 1 pam.
Taff Vale Ry. Co. 1 pam.
Talbot, Arthur N. 2 pam.
U. S.-Bureau of Mines. 3 pam.
U. S.-Bureau of Statistics. 1 pam.
U. S.-Bureau of the Census. 4 pam.
U. S.-Chf. of Engrs. 11 pam.
U. S.-Commr. of Lighthouses. 1 pam.
U. S.-Dept. of Agriculture. 2 pam.
U. S.-Dept. of the Interior. 1 pam.
U. S.-Forest Service. 2 pam.
U. S.-Interstate Commerce Comm. 51 pam.
U. S.-Lake Survey Office. 3 maps.
U. S.-Navy Dept. 1 vol.
U. S.-Office of Exper. Stations. 1 vol., 1 pam.
U. S.-Office of Naval War Records. 3 vol., 7 pam.
U. S.-Office of Public Roads. 3 pam.
Utah State School of Mines-Eng. Exper. Station. 2 pam.
Virginia, Univ. of. 1 vol.
Wisconsin-State Insp. of Illuminating Oils. 1 pam.
Wisconsin, Univ. of. 1 pam.
Worcester Polytechnic Inst. 1 vol.
Yale Univ. 1 vol.

BY PURCHASE

Handbuch für Eisenbetonbau: Brückenbau: Sechster Band. Zweite Auflage. Balkenbrücken. Bogenbrücken. Anwendungen des Eisenbetons im Eisenbrückenbau. Von W. Gehler. Th. Gesteschi; und O. Colberg. Wilhelm Ernst & Sohn, Berlin, 1911.

Illustrierte Technische Wörterbücher in Sechs Sprachen. Von Alfred Schlomann. 4 vol. Band VII, Hebemaschinen und Transport-Vorrichtungen. Band VIII, Der Eisenbeton im Hoch- und Tiefbau. Band X, Motorfahrzeuge. Band XI, Eisenhüttenwesen. R. Oldenbourg, München und Berlin: Constable and Co., Ltd., London: H. Dunod & E. Pinat, Paris, 1911.

American Highways: A Popular Account of Their Conditions and of the Means by Which They may be Bettered. By N. S. Shaler. The Century Co., New York, 1896.

Eagle Almanac, 1912: A Book of Information, General of the World and Special of New York City and Long Island. The Brooklyn Daily Eagle, New York.

A Handbook on the Gas Engine: Comprising a Practical Treatise on Internal Combustion Engines. By Herman Haeder. Translated from the German and Edited by W. M. Huskisson. Crosby Lockwood and Son, London, 1911.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, insbesondere aus den Laboratorien der technischen Hochschulen. Herausgegeben vom Verein deutscher Ingenieure. Hefte 110-111. Julius Springer, Berlin, 1911.

Handbuch der Ingenieurwissenschaften: Dritter Teil. Der Wasserbau: Die Gewässerkunde. Von J. F. Bubendey, P. Gerhardt, und R. Jasmund. Erster Band, vierte Auflage. Wilhelm Engelmann, Leipzig, 1911.

SUMMARY OF ACCESSIONS

(From January 5th to February 9th, 1912)

Donations (including 6 duplicates)	217
By purchase	11
Total	228

MEMBERSHIP

ADDITIONS

(From January 8th to February 10th, 1912)

MEMBERS		Date of Membership.
APPLETON, THOMAS ALLEN. 311 Essex St., Beverly, Mass.		Jan. 2, 1912
CARTER, RICHARD WILLIAM. Bridge Engr., Key West Extension, Florida East Coast Ry., Marathon, Fla.	Assoc. M. M.	Oct. 1, 1902 Jan. 2, 1912
ECKLES, HARRY EDWARD. 2923 Holmes St., Kansas City, Mo.		Dec. 5, 1911
GIBSON, JASPER MANLIUS. Secy. and Treas., Mulcahy & Gibson, Inc., 381 Fourth Ave., New York City		Feb. 6, 1912
HARMAN, JACOB ANTHONY. (Harman Eng. Co.), 120 Fredonia Ave., Peoria, Ill.	Assoc. M. M.	May 4, 1898 Jan. 2, 1912
HOWES, ROBERT. Cons. Engr., 1102 Am. Bank Bldg., Seattle, Wash.		Jan. 2, 1912
JOHNSTON, JOHN ALBERT. Div. Engr., Massachusetts Highway Comm., 65 Knowles Bldg., Worcester, Mass.		Feb. 6, 1912
KAFKA, FREDERICK PERCIVAL. Pres. and Mgr., The Herringbone Metal Lath Co., 257 East 133d St., New York City (Res., 49 Washington Ave., New Rochelle, N. Y.)	Assoc. M. M.	May 1, 1907 Jan. 2, 1912
LEITCH, JOHN. Res. Engr., East Indian Ry., Bankipore, Bengal, India		Dec. 5, 1911
MCCOY, LAURENCE FRANCIS. Div. Engr., Canadian Northern Ontario Ry., Nemegos, *via* Sudbury, Ont., Canada		Dec. 5, 1911
MUCKLESTON, HUGH BURRITT. Care, J. S. Dennis, Calgary, Alta., Canada		Jan. 2, 1912
NICHOLSON, MAURY. City Engr., City Hall, Birmingham, Ala.		Jan. 2, 1912
RUFFIN, CHARLES LORRAINE. Care, Black Mountain Ry., Burnsville, N. C.		May 2, 1911
WENTWORTH, CHARLES AUSTIN. Cons. Engr., 703 Empire Bldg., Philadelphia, Pa.	Assoc. M. M.	Oct. 7, 1903 Jan. 2, 1912

ASSOCIATE MEMBERS	
ANDREWS, ROBERT EDMUND. Engr., Committee on Fire Prevention, National Board of Fire Underwriters, 606 Grant Pl., Bay City, Mich.	Jan. 2, 1912
AVERY, CHARLES DWIGHT. P. O. Box 335, Cheyenne, Wyo.	Jan. 2, 1912
BARTLETT, CHARLES TERRELL. Civ. and Structural Engr. (Bartlett & Ranney), F Bldg., San Antonio, Tex.	Jan. 2, 1912
BOBBS, ARTHUR LEE. Cons. Structural Engr., 68 Post St., San Francisco, Cal.	Jan. 2, 1912

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
BORCHERS, PERRY ELMER. Contr. Engr., 218 National Bank of Arizona Bldg., Phœnix, Ariz.		Jan. 2, 1912
BORTIN, HARRY. Asst. Engr., U. P. R. R., 320 North 20th St., Omaha, Nebr.	Jun. Assoc. M.	Sept. 6, 1910 Jan. 2, 1912
BOWEN, EDWARD ROSE. 1110 Central Bldg., Los Angeles, Cal.		Jan. 2, 1912
BRETT, LAWRENCE. Pres. and Gen. Mgr., Brett Eng. & Contr. Co., Wilson, N. C.		Feb. 6, 1912
BYRD, JOHN HENRY. Engr. in Chg., Design, Bridges and Subways, Kansas City Terminal Ry., 4427 Troost Ave., Kansas City, Mo.		Jan. 2, 1912
CASANI, ALBERT AENEAS. Instr., Structural Design, School of Industrial Arts, Columbia University, 561 West 180th St., New York City		Jan. 2, 1912
CORY, WILLIAM EARLE. 1510 Franklin St., Boise, Idaho.		Jan. 2, 1912
CUNNINGHAM, JOHN EARL. American Felt Co., 246 Summer St. (Res., 2 Louisburg Sq.), Boston, Mass.	Jun. Assoc. M.	Sept. 5, 1905 Jan. 2, 1912
DURANT, ALDRICH. P. O. Box 1149, Havana, Cuba		Oct. 31, 1911
FAIRBAIRN, WILLIAM JAMES. Asst. Engr. of Constr., Board of Water Commrs., 274 Commonwealth Ave., Detroit, Mich.		Dec. 5, 1911
GALLIVAN, JAMES HENRY. Div. Engr., Central New England Ry., Cottage St., Poughkeepsie, N. Y.		Jan. 2, 1912
GARFIELD, CHESTER ARTHUR. Asst. Engr., New York City Board of Water Supply, West Shokan, N. Y.		Feb. 6, 1912
HARPER, FREDERICK CLAYTON. Western Mgr., Concrete Steel Co., 1106 Monadnock Blk., Chicago, Ill.	Jun. Assoc. M.	April 30, 1907 Jan. 2, 1912
HAYWOOD, CHARLES ELLSWORTH. Asst. Engr., Gibbs & Hill, Cons. Engrs., Room 715, Pennsylvania Station, New York City.	Jun. Assoc. M.	Nov. 8, 1909 Feb. 6, 1912
HILL, WALTER NICKERSON. Asst. Engr., U. S. Reclamation Service, St. Ignatius, Mont.		Jan. 2, 1912
HOUSTON, JOHN JAY LAFAYETTE. 19 Union Hall St., Jamaica, N. Y.		Jan. 2, 1912
KINGSLEY, EDGAR ALBERT. Supt. of Public Works, Little Rock, Ark.		Jan. 2, 1912
KLEIN, ALBERT ROBERT. Chf. Engr., Constr. Dept., Bosch Magneto Co., Springfield, Mass.		Jan. 2, 1912
KRAFFT, ALFRED JULIUS. Engr., J. E. Krafft & Sons, Phelan Bldg., San Francisco, Cal.		Jan. 2, 1912
KRAUSE, LOUIS GUSTAVE. Cons. Engr., 14 South Oakland Ave., Ventnor City, N. J.		Jan. 2, 1912
LEWIS, JOHN OVINGTON. 347 Twenty-first St., Brooklyn, N. Y.		Jan. 2, 1912

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
LOUGHRAN, HAROLD SCOTT. Prin. Asst. Engr., with L. E. Van Etten, Hillcrest Ave., New Rochelle, N. Y.	Jun. Assoc. M.	Jan. 2, 1906 Jan. 2, 1912
MCINTYRE, WILLIAM AINSWORTH. Engr. and Supt. of Highways for Lower Merion Township, Montgomery County, 1526 Land Title Bldg., Philadelphia, Pa.		Feb. 6, 1912
MILLER, EDWARD THOMAS EVERY. Ingeniero Seccional, Ferro Carril Central Argentino, Cordoba, Argentine Republic		Dec. 5, 1911
NEWCOMB, WILLIAM TAFT. Engr., Amies Road Co., 580 Bourse Bldg., Philadelphia, Pa		Feb. 6, 1912
NOBLE, GUY LYNN. Dist. Engr., Dept. of State Engr. and Surv., 315 Rosenbloom Blk., Syracuse, N. Y.		Feb. 6, 1912
NOYES, STEPHEN HENLEY. Care, Pennsylvania Steel Co., Steelton, Pa	Jun. Assoc. M.	Oct. 1, 1907 Feb. 6, 1912
O'BRIEN, WILLIAM ARTHUR. Chf. Engr., Little River Drainage Dist., 304 Himmelberger-Harrison Bldg., Cape Girardeau, Mo.		Jan. 2, 1912
ORRELL, JAMES ATHERSMITH. 7 Wakefield Rd., Bradford, England		Dec. 5, 1911
PEARSE, WILLIAM WORTH. First Vice-Pres. and Engr., Radley Steel Constr. Co., 624 East 19th St., New York City		Sept. 5, 1911
POLLOCK, GEORGE GORDON. Engr. and Asst. Mgr., Ross Const. Co., Box 727, Sacramento, Cal		Jan. 2, 1912
RAMSBOTHAM, JOSHUA FIELDEN. Box 81, Fremantle, Western Australia		Oct. 31, 1911
SAURBREY, HENRY ALEXIS D'ORIGNY. Chf. Engr., Ransome Eng. Co., 90 West St., New York City (Res., 1117 West Front St., Plainfield, N. J.)		Jan. 2, 1912
SEXTON, RALPH ERNEST. Care, Am. Bridge Co., Pencoyd, Pa		Oct. 3, 1911
SHANNON, WILLIAM DAY. Care, Stone & Webster Eng. Corporation, Sumner, Wash		Dec. 5, 1911
SIDENIUS, HARRY. Res. Engr., Canadian Pac. Ry., Irrig. Dept., Bassano, Alta., Canada		Jan. 2, 1912
SNODGRASS, ROBERT DAVIS. Chf. Engr., Trussed Concrete Steel Co., Detroit, Mich		Jan. 2, 1912
STERNS, FRANK ERNEST. Care, Chf. Engr., Culebra, Canal Zone, Panama		Jan. 2, 1912
STOCKING, JEROME BRANCH. Asst. Chf. Engr., Salmon River Canals, Hollister, Idaho		Jan. 2, 1912
STROMBERG, JULIAN WILLIS. 342 River St., Chicago, Ill.		Jan. 2, 1912
THON, GEORGE LOUIS. Asst. Engr., Alvord & Burdick, 1417 Hartford Bldg., Chicago, Ill		Oct. 3, 1911

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
TOMPKINS, WILLIAM ISRAEL. Contr. Engr., Massillon Bridge & Structural Co., Massillon, Ohio		Jan. 2, 1912
VAN PETTEN, ALBERT ALEXANDER. With Porto Rico Constr. Co., Bayamon, Comerio Falls, Porto Rico		Dec. 5, 1911
VAN VLECK, JAMES BRACKETT. Supt., Fruin-Colnon Constr. Co., 6182 McPherson Ave., St. Louis, Mo	Jun.	May 5, 1908
	Assoc. M.	Jan. 2, 1912
VENSANO, HARRY CHITTENDEN. Engr., Pac. Gas & Elec. Co., 445 Sutter St., San Francisco, Cal	Jun.	June 4, 1907
	Assoc. M.	Dec. 5, 1911
WAIT, BERTRAND HINMAN. Div. Engr., Board of Water Supply, 700 West 181st St., New York City		Jan. 2, 1912
WILSON, EDBERT CARSON. Engr., Lockwood Co., 139 Main St., Waterville, Me		Feb. 6, 1912
WILSON, WILLIAM. Architectural Engr. with Grosvenor Atterbury, 20 West 43d St., New York City		Feb. 6, 1912

ASSOCIATE

SMITH, JONATHAN RHODES. Engr., The Jobson Gifford Co., 25 East 26th St., New York City	Dec. 5, 1911

JUNIORS

BROOKS, RAYMOND WENTWORTH. Hartford, Iowa	Jan. 2, 1912
DE MEY, EDOUARD JEAN BERNARD. Levelman, Constr. Dept., B. & O. Southwestern R. R., 63 Carew Bldg., Cincinnati, Ohio	Jan. 2, 1912
ENGER, ARTHUR LUDWIG. Instr., Highway Eng., Polytechnic Inst., Brooklyn, N. Y	Jan. 2, 1912
FAIDLEY, LLOYD HARRISON. 4812 Hammett Pl., St. Louis, Mo	Dec. 5, 1911
GODFREY, STUART CHAPIN. Lieut., Corps of Engrs., U. S. A., Schofield Hall, Fort Leavenworth, Kans	Sept. 5, 1911
KAESTNER, ALBERT CARL. 2216 Starling Ave., New York City	Jan. 2, 1912
LONGWELL, JOHN STALKER. Junior Engr., U. S. Reclamation Service, Boise, Idaho	Oct. 3, 1911
MCWILLIAMS, SAMUEL ALEXANDER. Morrowville, Kans	Oct. 3, 1911
MASSEI, CAESAR. Structural Draftsman, Virginia Bridge & Iron Works, 501 Eleventh Ave., S. W., Roanoke, Va	Jan. 2, 1912
MILLER, GARNER WAKEFIELD. Instrumentman and Office Engr., W. E. Ayres, 616 Randolph Bldg., Memphis, Tenn	Jan. 2, 1912
MUDD, JOHN POSEY. Engr., Midvale Steel Co., Philadelphia, Pa	Jan. 2, 1912

JUNIORS (*Continued*)	Date of Membership.
RHEINSTEIN, ALFRED. 344 West 89th St., New York City..	Jan. 2, 1912
ROLFE, ROBERT LAWRENCE. P. O. Box 1027, Memphis, Tenn.	Sept. 5, 1911
ROSSI, IRVING. Structural Draftsman, Milliken Bros., Inc., 138 Carteret Ave., Jersey City, N. J.	Jan. 2, 1912
SPENCER, CHARLES BURR. Asst. Engr., R. F. Almirall, 1124 Pinton Ave., New York City	Oct. 3, 1911
STONE, GEORGE CARTER. Reinforced Concrete Draftsman, Lockwood, Greene & Co., 138 Lauriat Ave., Dorchester, Mass	Jan. 2, 1912
THOMPSON, JAMES ARTHUR. Levelman, Interborough Rapid Transit Co., 32 Park Pl., New York City	Jan. 2, 1912
THORNE, HOWARD SLOAN. Supt. of Constr. for George F. Mills, 131 West Bancroft St., Toledo, Ohio	Sept. 5, 1911
WEST, EDWARD HAZZARD. U. S. Junior Engr., Box 72, Louisville, Ky	Jan. 2, 1912

REINSTATEMENT

ASSOCIATE MEMBER	Date of Reinstatement.
HOVEY, RAY PALMER	Feb. 6, 1912

RESIGNATIONS

MEMBERS	Date of Resignation.
RUPLE, COMMODORE PERRY	Feb. 6, 1912
JUNIORS	
ALEXANDER, LEON BARTON	Feb. 6, 1912
SCHUMANN, CARL JULIUS	Feb. 6, 1912

DEATHS

BENNETT, FREDERICK WAGONER. Elected Member, October 7th, 1903; died January 8th, 1912.

CLAPP, WILLIAM BILLINGS. Elected Member, December 6th, 1905; died December 26th, 1911.

ELLIS, SAMUEL CLARENCE. Elected Member, August 7th, 1872; died January 21st, 1912.

FARREN, B. N. Elected Fellow, March 12th, 1870; died January 21st, 1912.

KINGMAN, LEWIS. Elected Member, July 1st, 1885; date of death unknown.

LEATHER, BASIL HENRY. Elected Associate, June 1st, 1904; died Oct. 31st, 1911.

LOFLAND, HENRY FIDDEMAN. Elected Member, June 2d, 1897; died January 14th, 1912.

MELCHER, FRANK OTIS. Elected Member, March 3d, 1897; died January 22d, 1912.

SMITH, JOSEPH SHUTER. Elected Member, April 1st, 1874; died March 26th, 1907.

TAUBENHEIM, ULRICH. Elected Associate Member, February 1st, 1905; died December 19th, 1911.

WHITE, GEORGE HOWARD. Elected Member, May 2d, 1883; died December 29th, 1911.

Total Membership of the Society, February 10th, 1912, 6 364.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(January 6th to February 8th, 1912)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.* ·

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1317 Spruce St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $4.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Transactions,* Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World,* 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 15c.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England.
(70) *Engineering Review,* New York City, 10c.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 10c.
(77) *Journal,* Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen,* Vienna, Austria.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Progressive Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings* Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(94) *The Boiler-Maker,* New York City, 10c.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., 219 Market St., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $1.50.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington. D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Mining Engrs., London, England, 6 shillings.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.

LIST OF ARTICLES.

Bridges.

An Exceptional Repair Job on a Swing Type Bridge.* (94) Jan.
The Interlocking of the Opening Bridges over the River Lee, Cork.* (21) Jan.
Moving a Heavy Bridge Span into Place.* (87) Jan.
Rolling Loads on Bridges. J. E. Greiner. (From *Bulletin,* Ry. Eng. Assoc.) (87) Jan.
Waterproofing a Bridge Floor over a City Water Supply.* (13) Jan. 4.
The Construction of a Model Bridge in Iowa.* C. B. McCullough. (Abstract from *Good Roads.*) (96) Jan. 4.
Operating Mechanism of the Bascule Span of the Passyunk Avenue Bridge.* (14) Jan. 6.
A Century Old Chain Suspension Bridge.* (62) Jan. 8.
New Foundations for the C. P. R. Lachine Bridge.* (96) Jan. 18.
Erection of Rock Island Bridge Over Iowa River, Columbus Junction, Iowa.* (15) Jan. 19.
Sawing Piling Under Water.* (15) Jan. 19.
Plate-Girder Tables. (13) Jan. 25.

---

*Illustrated.

Bridges—(Continued).

Replacing Worn Bridge Pins in the Field.* H. C. Lothholz. (13) Jan. 25.
An Electric Hoist Traveler for Placing the Concrete Floor of a Viaduct.* C. M. Kurtz. (13) Jan. 25.
Rodbridge, Long Melford, Ferro-Concrete Replaces Timber Structure.* (104) Jan. 26.
The Keystone Bridge of the Western Maryland Railway.* Walter Shultz. (14) Jan. 27.
Method of Estimating Cost of Standard Reinforced Concrete Highway Bridges of Illinois Highway Commission, Through Girder and Slab Types.* B. H. Piepmeir. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) Jan. 31; (14) Feb. 3.
A New Double-Track Railroad Bridge over the Rhine near Homberg.* Wernckke. (14) Feb. 3.
The Reinforced Concrete Viaduct at Gilbert Avenue, Cincinnati.* Frank L. Raschig. (86) Feb. 7.
Les Nouveaux Ponts de Constantine (Algérie).* G. Leinekugel Le Cocq. (33) Dec. 30.
Ponts Basculants du Canal Maritime de Bruxelles à Laeken, près Bruxelles.* (33) Jan. 20.
Zweigleisige Eisenbahnbrücke über den Rhein unterhalb Duisburg-Ruhrort im Zuge der Linie Oberhausen-West-Hohenbudberg.* Schaper. (49) Serial beginning Pt. 10, 1911.
Das Stützliniengewölbe mit lotrecht wirkender Ueberlast. A. Hofmann. (81) Pt. 1, 1912.
Eisenbeton-Brücken im bayerischen Hochland.* Leonard Moll. (51) Sup. No. 2.

Electrical.

Worcester Electricity Supply Developments.* (26) Dec. 29.
Reactance in Alternating Current Circuits. C. P. Steinmetz. (4) Jan.
Poynting's Theorem and the Equations of Electro-Magnetic Action.* W. S. Franklin. (3) Jan.
Continuous-Current Motors with Commutating Poles and Cast-Iron Magnets.* J. W. Burleigh. (26) Jan. 5.
Electricity Supply at Keighley.* Harry Webber. (26) Jan. 5.
Field-Control Problems in Direct Current Machines.* William G. Merowitz. (27) Jan. 6.
The Manufacture and Performance of the Edison Storage Battery.* Howard Lyon. (46) Jan. 6.
110 000 Volt Transmission System of the Province of Ontario.* (27) Jan. 6; (27) Jan. 13.
General Specifications for Underground Electric Conduit. R. E. Froisetti. (86) Jan. 10.
The Single-Phase Repulsion Motor.* Thomas F. Wall. (Paper read before the British Assoc.) (11) Serial beginning Jan. 12.
Duddell-Mather Wattmeters for Measuring Dielectric Losses at 30 000 Volts.* (73) Jan. 12.
Electric Power for the Panama Canal.* John Geo. Leigh. (26) Serial beginning Jan. 12.
Electrical Plant at the Buxton Lime Firm's Quarries.* (26) Jan. 12.
Electrical Development in Industrial Areas. L. Crouch. (26) Serial beginning Jan. 12.
Electrical Equipment of a Great Group of Office Buildings.* Henry C. Meyer, Jr., and Bassett Jones, Jr. (27) Jan. 13.
Electrical Equipment for McCalls Ferry; Transformers Just Placed at Baltimore Sub-Station of Power Company Attract Much Attention.* (62) Jan. 15.
Tests of a 2 880-kw. Rebuilt Hydro-Electric Unit at the Kern River Plant of the Pacific Light and Power Company.* G. J. Henry and J. H. Hansen. (13) Jan. 18.
The Speed Control of Large Induction Motors.* N. Shuttleworth. (Paper read before the Rugby Eng. Soc.) (12) Jan. 19.
A Determination of the International Ampere in Absolute Measure. E. B. Rosa, N. E. Dorsey and J. M. Miller. (Abstract from *Journal* of the Washington Academy of Sciences.) (73) Jan. 19.
The New Avenue Exchange.* (21) Jan. 19; (73) Jan. 12.
A New Type of Fluxmeter.* B. H. Morphy and U. S. Oschwald. (73) Jan. 19.
Late Researches in Electrolysis. (14) Jan. 20.
The Properties of Selenium and Their Application in Electrotechnics.* Erich Hausmann. (19) Serial beginning Jan. 20.
Electrolysis of Pipes in Chicago. Ray Palmer. (Abstract of report to Chic. City Council.) (13) Jan. 25.
Calculations for 1 000 Spark Frequency. Shunkichi Kimura. (73) Jan. 26.
Heat Tests of Alternate-Current Transformers.* J. T. Morris, J. W. Elliott and D. Lewes. (73) Jan. 26.

*Illustrated.

Electrical—(Continued).

Wireless Telegraphy on the Atlantic Coast of the United States. James L. Charlton. (27) Jan. 27.
A Method of Studying Power Costs with Reference to the Load Curve and Overload Economies.* George I. Rhodes. (42) Feb.
The Relative Costs and Operating Efficiencies of Polyphase and Single-Phase Generating and Transmitting Systems. H. M. Hobart. (42) Feb.
Electrical Power in the Transvaal.* Rowland Gascoyne. (10) Feb.
Handling Lumber with Electric Monorail Hoists.* (27) Feb. 3.
Central-Station Load Factors.* E. F. Tweedy. (27) Feb. 3.
Low Rates and the Development of the Central Station Service. W. E. Burnand. (27) Feb. 3.
A Philadelphia Theater Electrical Equipment.* (27) Feb. 3.
New Hydroelectric Plant of Northern California Power Co.* Rudolph W. Van Norden. (27) Feb. 3.
Switchboard Panels for Three-Wire Generators.* A. M. B. Bennett. (27) Feb. 3.
Note sur l'Electrolyse des Cuivres Impurs en Liqueur Sulfurique (Moyen pour Conserver les Bains et Assurer l'Obtention d'un Bon Dépot aux Cathodes). M. Vuigner. (93) Jan.
Phénomènes Spéciaux Accompagnant la Rupture des Filaments Incandescents dans les Mélanges d'Air et de Gaz Combustibles.* H. Couriot et J. Meunier. (33) Jan. 20.
L'Etude des Distances Explosives avec les Courants Alternatifs.* (33) Jan. 27.

Marine.

Development of the Marine Boiler in the Last Quarter Century. George W. Melville. (9) Jan.
Keeping a Dredge in Operation.* T. T. (108) Jan.
H. M. Battle-Cruiser *Lion*.* (11) Jan. 5.
Coal Shipping Plant.* (22) Jan. 5.
The Armament and Protection of Battleships.* Salvatore Orlando. (Abstract of translation of Italian paper read before the Congresso Nazionale di Ingegneria Navale e Meccanica.) (11) Jan. 12.
Propeller Erosion.* (11) Jan. 12.
The Gas Driven Vessel *Holzapfel I*.* (46) Jan. 13.
The Carels Diesel Marine Engine.* (11) Jan. 19.
Engineering Works at the Rosyth Naval Dockyard.* (11) Serial beginning Jan. 19.
The Corrosion of Condenser Tubes by Contact with Electro-Negative Substances. Arnold Philip. (Paper read before the Inst. of Metals.) (11) Serial beginning Jan. 19; (47) Jan. 26.
Panama Canal Dredge *Corozal*. Wm. G. Comber. (13) Jan. 25.
The Cunard Liner *Laconia*.* (12) Jan. 26.
The Three-Gun Turrets of the New Battleships.* (46) Jan. 27.
Steam Turbines for Auxiliary Purposes on Board Ship.* Ernest N. Janson. (95) Feb.
New Menhaden Steamers for the Atlantic Coast.* Martin C. Erismann. (95) Feb.
Le Cuirassé-Croiseur *Lion* de la Marine britannique. M. Gouriet. (33) Jan. 20.
Die neuen Werft- und Hafenanlagen in Wilhelmshaven.* Moeller und Behrendt. (49) Serial beginning Pt. 1, 1912.

Mechanical.

Gas-Producers.* J. Emerson Dowson. (75) April, 1911.
The Effect of Varying Proportions of Air and Steam on a Gas-Producer.* E. A. Allcut. (75) April, 1911.
Tool Steel. W. B. Sullivan. (65) Nov. 17.
Sixty-Ton Electric Overhead Cranes.* (12) Dec. 29.
North Eastern Railway Company's New Boiler Shop at Darlington.* (12) Dec. 29.
Double Cantilever 120-Ton Floating Crane at the Pola Dockyard.* (11) Dec. 29.
New Electrical Crane Installation at the Grimsby Docks.* (26) Dec. 29.
Methods of Dealing with Losses in Steam Plant Due to Condensation.* George and J. R. Wilkinson. (Paper read before the Assoc. of Engrs. in Charge.) (73) Dec. 29; (47) Jan. 12.
Power System of the Pacific Mills, Methods and Rules for, and Cost of Operation. Fred. A. Wallace. (Paper read before the Boston Soc. of C. E.) (1) Jan.
Gasification of Solid Fuel. Charles Edward Lucke. (9) Serial beginning Jan.
Cost Data of Power-Plant Installation and Operation. W. H. Weston. (9) Jan.
Preliminary Drying.* (Clay Manufacture.) Hartley M. Phelps. (76) Jan. 1.
Lockland Brick Plant.* (76) Jan. 1.
Power Requirements of Rolling Mills.* Samuel S. Roberts. (20) Jan. 4.
Accident Prevention in Steel Plants.* Robert J. Young. (20) Jan. 4.
Evansville Plant of the Bucyrus Company. (20) Jan. 4.
Motor-Car Engine Tests.* J. A. Moyer. (13) Jan. 4.

*Illustrated.

Mechanical—(Continued).

Design of Oil-Fired Open-Hearth Furnaces.* W. Macgregor. (47) Jan. 5.
Osborn's Spark-Arrester for Cupolas.* (11) Jan. 5.
Problem of Machine Tool Standardisation.* L. P. Alford. (47) Jan. 5.
Making the Starting Crank Obsolete.* H. P. Wilkin. (46) Jan. 6.
Rustless Coatings for Iron and Steel in Gas-Works.* Alwyne Meade, Assoc. M. Inst. C. E. (66) Jan. 2.
The Application of Blue Water Gas to Industrial Processes.* Alwyne Meade, Assoc. M. Inst. C. E. (66) Jan. 9.
Power Requirements of a Steel Tube Mill.* A. S. Ahrens. (From *The Electric Journal.*) (47) Jan. 12.
Cause and Prevention of Blowholes in Composition and Bronze Castings. (From *The Brass World.*) (47) Jan. 12.
Temporary Power Plant for Woolwich Footway Tunnel.* (12) Jan. 12.
Continuous Gas-Fired Muffle Kiln.* (76) Jan. 15.
Unique Electric Station Coal Handling Plant.* Frank C. Perkins. (62) Jan. 15.
The New Gas Plant, Société Anonyme du Gaz de Rio Janeiro, Brazil.* L. J. Carder. (24) Jan. 15.
Production and Market for Sulphate of Ammonia. W. N. McIlravy. (Paper read before the Am. Gas. Inst.) (83) Jan. 15.
Smoke Prevention With Steam Jets.* J. A. Switzer. (64) Jan. 16.
Prevention of Industrial Accidents.* (20) Jan. 18.
The United States Overfeed Stoker.* (20) Jan. 18.
Properties of Air and Steam Mixtures in Relation to Condensing Plant.* Thomas B. Morley. (11) Jan. 19.
The Simon-Carves By-Product Recovery Process.* (22) Jan. 19.
Lignite Fuel for Locomotives.* (15) Jan. 19.
Some Principles of Condensation with Especial Reference to Water Gas.* L. E. Worthing. (Paper read before the Am. Gas Inst.) (24) Serial beginning Jan. 22.
Comparative Costs and Efficiency of Gas, Electric and Gasoline Lighting.* W. M. Blinks. (Paper read before the National Commercial Gas Assoc.) (24) Serial beginning Jan. 22.
The Effectual Working of a Carburetted Water-Gas Plant. Alwyne Meade, Assoc. M. Inst. C. E. (66) Jan. 23.
The Junkers Oil Engine.* F. E. Junge. (64) Jan. 23.
Measurement of Hot Feed Water.* J. A. Knesche. (64) Jan. 23.
130-Ton Steam Shovel for Rock Work.* (13) Jan. 25.
Steam Shovel Dipper Trips used on the Panama Canal.* (Abstract from *Canal Record.*) (13) Jan. 25.
The Use and the Abuse of Fuel. Reginald Pelham Bolton. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (101) Jan. 26.
Air Compressor Efficiency.* B. M. Woodhouse. (Paper read before the Rugby Eng. Soc.) (47) Jan. 26.
The Creusot Iron Works.* (19) Jan. 27.
British Practice in Superheating.* Victor White. (64) Jan. 30.
The Distribution of Gas: Problems and Solutions.* James Hewett. (Paper read before the Midland Junior Gas Assoc.) (66) Jan. 30.
Kirkintilloch Gas-Works Boosting Plant. James Bell. (Paper read before the Scottish Junior Gas Assoc.) (66) Jan. 30.
Modern Developments in American Motor Fire-Apparatus.* (9) Feb.
Modern Testing Machines.* C. A. M. Smith. (10) Serial beginning Feb.
A Survey of American Gas Photometry.* Charles O. Bond. (Paper read before the Am. Gas Inst.) (83) Feb. 1.
Tests of Old Boilers.* Alex M. Gow. (13) Feb. 1.
Strain Measurements of Steam Boilers.* (96) Feb. 1.
Comparison of Commercial Economy of Gas Engines and Steam Turbines. Franklin M. Farwell. (27) Feb. 3.
Temperature Pendants Convenient Means for Determining Flue Gas Temperatures.* (19) Feb. 3.
Pipe Yard and Shops of the Reading Water Department.* Emil L. Nuebling. (14) Feb. 3.
A Reinforced Concrete Locomotive Coaling Station.* (14) Feb. 3.
The Manufacture of Artificial Ice as a Central Station By-Product. Sydney F. Walker. (27) Feb. 3.
The Barnhart Technical Gas Analysis.* (24) Feb. 5.
Lubricants, Their Properties and Uses. Robert Jeffrey. (Paper read before the Practical Refrigerating Engrs.' Assoc.) (64) Feb. 6.
Oil Burning with Different Settings.* (From *Bulletin,* Louisiana State Univ. and A. and M. Coll.) (64) Feb. 6.
Some Notes on the Development of Motor Trucks for Contractors' Service, with Data Concerning Operating Cost.* (86) Feb. 7.
Etude sur la Production du Vide et Certaines de ses Applications.* Maurice Leblanc. (32) Nov.; (92) Dec.
Mise en Briquettes des Tournures Métalliques et leur Valeur en Fonderie de Fer et de Bronze.* Oscar Leyde. (93) Jan.

*Illustrated.

Mechanical—(Continued).

Deformationswiderstand, tangentiale Kohäsion und Reibungswiderstand von Flüssigkeiten; ein Beitrag zur hydrodynamischen Theorie der Schmiermittelreibung.* M. Reiner. (53) Dec. 22.
Das Märkische Elektrizitätswerk.* G. Klingenberg. (48) Serial beginning Dec. 23.
Die Eisen- und Stahlgiesserei der Société Française de Constructions Mécaniques in Denain.* J. Leber. (50) Dec. 28.
Luftwiderstandsversuche mit grösseren Aeroplanflächen.* A. von Parseval. (48) Dec. 30.
Versuche über die Spannungsverteilung in Kranhaken.* E. Preuss. (48) Dec. 30.
Beitrag zur Berechnung der Schraubenfedern.* H. Al. Siebeck. (48) Dec. 30.
Das Fräsen von Zahnrädern.* C. Brückner. (48) Dec. 30.
Beitrag zur Kenntnis des Kraftbedarfs von Träger-, Draht- und Blechstrassen.* J. Puppe. (50) Jan. 4.
Das hydrodynamische Getriebe von Föttinger.* H. Hoff. (50) Jan. 11.
Brikettieranlagen zur Herstellung von Eisen- und Metallspäne-Briketts der Hochdruckbrikettierung G. m. b. H. in Berlin.* J. Mehrtens. (50) Jan. 25.
Maschinelle Entladung von Mauersteinen.* (80) Jan. 27.

Metallurgical.

Steel.* Walter Rosenhain. (75) April, 1911.
Tool Steel. W. B. Sullivan. (65) Nov. 17.
Heating Steel in Hot Lead. E. R. Markham. (108) Dec.
Electrical Iron Smelting in Sweden. Thomas Duncan Robertson. (Abstract of paper read before the Am. Electro-Chemical Soc.) (47) Dec. 29.
Electric Smelting and Reduction of Ore in England. J. Härdén. (73) Dec. 29.
High-Extraction Processes in the Metallurgy of Gold and Silver.* T. Lane Carter. (9) Jan.
Plate and Merchant Mills at Haselton, Ohio.* (20) Jan. 4.
The Sintering of Iron Bearing Materials.* James Gayley. (20) Jan. 4.
The Carbonizing of Steel by the Use of Gases.* E. F. Lake. (20) Jan. 4.
Progress in Cyanidation of Gold and Silver Ores During 1911.* Alfred James. (103) Jan. 6.
Colorado Metallurgical Progress.* P. H. Argall. (103) Jan. 6.
Metallurgy of Iron and Steel. Bradley Stoughton. (16) Jan. 6.
Stamp Milling in 1911. Louis D. Huntoon. (16) Jan. 6.
Casting Steel and Alloys in a Vacuum.* E. F. Lake. (20) Jan. 11.
Electric Smelting in Sweden.* C. Van Langendonck. (13) Jan. 11.
Notes on Pyritic Smelting. George A. Guess. (16) Jan. 13.
Igneous Concentration of Zinc Ore. F. L. Clerc. (16) Jan. 13.
Strength of Alloys at High Temperatures.* G. D. Bengough. (Paper read before the Inst. of Metals.) (11) Serial beginning Jan. 19.
New Blast Furnace at the Works of the Barrow Hematite Steel Company, Limited.* (22) Jan. 19.
A New Electric Resistance Furnace. F. A. J. Fitzgerald. (Abstract of paper read before the Am. Electro-Chemical Soc.) (73) Jan. 19.
On the Behavior of Certain Alloys when Heated in Vacuo. Thomas Turner. (Paper read before the Inst. of Metals.) (47) Jan. 26.
Practical Applications of the Specific Gravity Flask.* H. Stadler. (Abstract from *Journal*, Chemical, Metallurgical and Mining Society of South Africa.) (103) Jan. 27.
Concentration of Molybdenite Ores.* Henry E. Wood. (16) Jan. 27.
Refining of Base Bullion.* W. Poole. (45) Feb.
Engineering Features of Electric Furnaces.* Carl Hering. (9) Serial beginning Jan. (105) Feb.
Recent Improvements in Filtration Methods.* (For Metallurgy). Ernest J. Sweetland. (Paper read before the Am. Chemical Soc.) (105) Feb.
Sinter-Roasting with Dwight-Lloyd Machines at Salida, Colo.* (105) Feb.
The Latest Thin-Lined Blast Furnace.* (20) Feb. 1.
The Production of Sound Steel.* Robert A. Hadfield. (20) Feb. 1.
The Slow Speed Chilean Mill. J. B. Empson. (Abstract of paper read before the Mexican Inst. of Min. and Metallurgy.) (16) Feb. 3.
Progrès des Métallurgies autre que la Sidérurgie et leur Etat Actuel en France.* Léon Guillet. (32) Oct.
Le Zingage du Fer et de l'Acier. M. Sang. (93) Jan.
Untersuchungen über die Zusammensetzung des Gasstromes im Hochofen.* M. Levin und H. Niedt. (50) Dec. 28.
Ueber Staubbestimmungen in Gichtgas. O. Johannsen. (50) Jan. 4.

Military.

The New Vickers Light Automatic Rifle-Caliber Gun and its Adjustable Mounting.* (46) Feb. 3.

*Illustrated.

Mining.

Coal Face Conveyors.* Harold H. Ridsdale. (106) Vol. 42, Pt. 2.
The Walker Overwinding-Prevention Gear for Colliery Winding-Engines, as Fitted at the Mary Pit of the Lochgelly Iron & Coal Company, Limited.* John Paul. (106) Vol. 42, Pt. 2.
The Working of the Thick Coal-Seams of Upper Silesia. Berent Conrad Gullachsen. (106) Vol. 42, Pt. 2.
British Coal Dust Experiments. W. E. Garforth. (106) Vol. 42, Pt. 2.
Accidents in Mines Caused by Falls of Grcund. George B. Harrison. (106) Vol. 42, Pt. 2.
Description of the Aerial Ropeway from the Shale-Mines to the Oil Works at Oakbank, Mid-Calder.* (106) Vol. 42, Pt. 2.
The Past, Present and Future of the Gold Mining Industry of the Witwatersrand, Transvaal. Frederick Henry Hatch. (63) Vol. 186.
Engineering Requirements in Bituminous Coal Mining. William E. Fohl. (58) Dec.
The Use of Electricity in the Treatment of Magnetic Ores.* (26) Dec. 29.
The Rogers Concrete Drop-Shaft, Iron River, Michigan.* P. B. McDonald. (103) Dec. 30.
Manganese Mining in British India. Herbert A. Carter. (103) Dec. 30.
Power for Cobalt Mines, Cobalt, Ontario. Cecil B. Smith. (Paper read before the Oregon Soc. Engrs.) (1) Jan.
The Tungsten Deposits of Boulder Co., Colorado. William E. Greenawalt. (36) Jan.
Automatic Sprinkling Apparatus for the Prevention of Dust in Mines.* T. Campbell Futers. (57) Jan. 5.
The Equipment and Works of the Fife and Clackmannan Joint Colliery Rescue Station.* Robert Crawford. (Paper read before the Scottish Branch of the National Assoc. of Colliery Mgrs.) (22) Jan. 5.
Gold-Dredging on Seward Peninsula.* T. M. Gibson. (103) Jan. 6.
Birley Collieries, Sheffield.* (22) Jan. 12.
Methods of Raising a Shaft on Timber in Hard Rock.* S. J. Goode. (Abstract of paper read before the Lake Superior Min. Inst.) (86) Jan. 17.
A Battery Sub-Station Plant at Hucknall Colliery.* G. C. Allingham. (26) Jan. 19.
Mining in the Belgian Congo, West Africa, for 1911.* Sydney H. Ball. (103) Jan. 20.
The Position on the Comstock.* George J. Young. (16) Jan. 20.
Some Phases of the Coal-Dust Question. W. Galloway. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) Jan. 26; (57) Jan. 26.
Aerial Ropeway for a Shropshire Quarry.* (12) Jan. 26.
Notes on the Operation of Two Winding Engines.* Humphrey M. Morgans. (57) Jan. 26.
Mining Ore at the Talisman Mine, N. Z.* (45) Feb.
Mine No. 3, Saline County Coal Co.* Oscar Cartlidge. (45) Feb.
Cross Mountain Mine Explosion.* (45) Feb.
Relieving Accumulations of Gas.* W. H. Cunningham and C. R. Connor. (45) Feb.
Some Interesting Cases of Shaft Sinking.* John S. Franklin. (10) Feb.
Oil.* Herman Frasch. (Paper read before the Am. Chemical Soc. and Am. Electrochemical Soc.) (105) Feb.
Recent Developments in Explosives. A. E. Anderson. (Paper read before the Colorado School of Mines and the Colorado Scientific Soc.) (16) Feb. 3.

Miscellaneous.

The Obstacles to the Progress of Meteorology. Cleveland Abbe. (3) Jan.
New Seismometers and Artificial Earthquake. (11) Jan. 5.
Note à Propos d'un Mémoire de M. Jean Rey Intitulé Quelques Remarques sur la Constitution Intérieure du Globe Terrestre.* F. Guery. (32) Oct.
Fern-Pyrometer von Fournier.* Schmidt. (102) Jan. 15.

Municipal.

The Improvement of Highways to Meet Modern Conditions of Traffic. Jonah Walker Smith. (63) Vol. 186.
Recent Developments in Road-Traffic, Road Construction and Maintenance.* Henry Percy Maybury. (63) Vol. 186.
Concrete Sidewalks. S. B. Code. (96) Jan. 4.
The Strengthening and Improvement of Road Crusts; Road Board's Circular to English and Welsh County Councils. (104) Jan. 5.
Wood Block Pavements in Chicago. John Ericson. (Abstract of Report to Commr. of Public Works.) (14) Jan. 6; (86) Jan. 17.
The Chemistry of Modern Highway Engineering. Prevost Hubbard. (Abstract of paper read before the Am. Assoc. for the Advancement of Science.) (86) Jan. 10.
Removing Pittsburgh's Hump.* (13) Jan. 11.

*Illustrated.

Municipal—(Continued).

Surfacing an Existing Road with Steam Rolled Water-Bound Macadam; Road Board Specification No. 7. (104) Jan. 12.
The Coleman du Pont Road Across Delaware. (14) Jan. 13.
A Heating Attachment for Concrete Mixers.* (For Paving.) (13) Jan. 18.
Highway Construction and Maintenance in Massachusetts. (14) Jan. 20.
Some Costs of Laying Fiber Conduits in Paved Streets. William D. Ligon. (86) Jan. 24.
Cost of Street Sprinkling in a Small City. E. W. Robinson. (86) Jan. 24.
Skating Rinks above Waterworks Reservoirs, Reading, Penn.* Mandes Golder. (13) Jan. 25.
Wood Paving Experiments in Minneapolis. (14) Jan. 27.
Surface Treatment of Park Roads in Washington, D. C. Spencer Cosby. (Paper read before the Am. Assoc. for the Advancement of Science.) (86) Jan. 31.
Modern Developments in American Motor Fire-Apparatus.* (9) Feb.
Practical Road Building.* John N. Edy. (60) Feb.
Stone Pavements of England and America.* Ernest Flagg. (From *The Century Magazine.*) (60) Feb.
The Park Heights Experimental Road, Baltimore, Md.* D. M. Avey. (60) Feb.
Bituminous Macadam Construction. A. N. Johnson. (Paper read before the Indiana Eng. Soc.) (60) Feb.
Bituminous Roads. W. W. Crosby. (Paper read before the Am. Assoc. for Highway Improvement.) (96) Feb. 1.
The Water Tower; A New Type of Horseless Fire-Fighting Truck.* (19) Feb. 3.
British Suggestions for Resurfacing an Old Road. (14) Feb. 3.
History of the Washington Bituminous-Concrete Pavements. Mark Brooke. (Paper read before the Am. Assoc. for the Advancement of Science.) (14) Feb. 3.
Suggestions on Methods of Lighting Streets and Comparative Costs of Various Methods. J. M. Bryant and H. G. Hake. (From *Bulletin,* Univ. of Illinois Eng. Exper. Station.) (86) Feb. 7.
La Lutte contre l'Usure et la Poussière des Routes, Quelques Solutions Economiques du Problème. A. Sallé. (35) Serial beginning Jan.

Railroads.

The Electrification of a Portion of the Suburban System of the London, Brighton and South Coast Railway.* Philip Dawson. (63) Vol. 186; (11) Jan. 26.
The Pennsylvania Railroad's New York Improvement.* Wm. B. McCaleb. (98) Dec.
Signaling and Interlocking.* J. A. Peabody. (4) Dec.
The New Passenger Terminal of the Chicago and North Western Railway.* W. C. Armstrong. (4) Dec.
Terminal Brake Testing. F. B. Farmer. (61) Dec. 19.
Superheater Goods Engine, Midland Railway.* (12) Dec. 29.
Overhead Single-Phase Railway Equipments on the Chemins de Fer du Midi.* (11) Dec. 29.
Baltic Type Locomotives at Work.* (12) Dec. 29.
Overhead Construction on the Dessau-Bitterfeld Railway.* Werner Usbeck. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Dec. 29.
Electrification of Railways.* E. O. O'Brien. (Paper read before the Manchester Soc. of Engrs.) (47) Serial beginning Dec. 29.
The Wimperis Accelerometer and Equilibristat.* H. E. Wimperis. (88) Jan.
The Relation of Railroads as Common Carriers to the State and Federal Governments. James C. Davis. (4) Jan.
Superheated Steam and Compound Engines; Paris, Lyons, Mediterranean Ry. (21) Jan.
Carbondale Tie-Treating Plant.* (87) Jan.
The Railroad Problem: Rates, Unit Costs and Efficiency.* F. Lincoln Hutchins. (9) Jan.
2-6-2 Tank Locomotive.* (21) Jan.
Earl's Patent Heating Apparatus for Railway Carriages.* (21) Jan.
2-8-0 Goods Engine; Great Central Railway.* (21) Jan.
Panama R. R. Relocation and Construction.* (Abstract from Annual Report of the Isthmian Canal Comm. (87) Jan.
Electric Train Lighting Instruction Car, Pennsylvania Railroad.* (21) Jan.
The Ideal Cab Signal.* (21) Jan.
The Practical Application of Scientific Management to Railway Operation.* Wilson E. Symons. (3) Jan.
Rules for Inspection and Testing of Locomotive Boilers. (Paper read before the U. S. Interstate Commerce Comm.) (94) Jan.
Machines for Handling Railway Ties.* R. P. Black. (13) Jan. 4.
The First Transandine Railway.* F. T. McGinnis. (13) Jan. 4.
British Standard Specifications for Material Used in Railway Rolling Stock. (47) Jan. 5.
Handling Freight with Motor Trucks at the Erie Terminal in Jersey City.* (14) Jan. 6.

*Illustrated.

Railroads—(Continued).

The Garratt Locomotive.* (18) Jan. 6.
The 50 000th Locomotive of the American Locomotive Co.* (18) Jan. 6.
Results of Electrical Operation of the Hoosac Tunnel.* (18) Jan. 6.
Engine Failures. Nels Osgaard. (Abstract from paper read before the Northern Railway Club.) (18) Jan. 6.
British Columbia Electric Locomotives.* (17) Jan. 6.
Compound Goods Locomotive for the Italian State Railways.* (11) Jan. 12.
The Closed-Circuit Crude Oil Locomotive.* (12) Jan. 12.
Cork City Railways.* (12) Jan. 12.
Effect of Cold Weather on Tonnage Rating.* Edward C. Schmidt. (Abstract of paper read before the Central Ry. Club.) (15) Jan. 12; (14) Jan. 13.
Mikado Superheater Locomotives for the Missouri Pacific.* (15) Jan. 12.
Building a Double-Track Section Around a Single-Track Railroad Tunnel. (14) Jan. 13.
Track Construction for an Electrified Suburban Road (N. Y., Westchester & Bost. Ry.). (14) Jan. 13.
Improved Method of Treating Ties and Timbers.* W. F. Goltra. (18) Jan. 13; (15) Jan. 12.
The Longitudinal Railway of Chile.* (12) Jan. 19.
Treating Seasoned vs. Unseasoned Ties. F. J. Angier. (Abstract of paper read before the Wood Preservers' Assoc.) (15) Jan. 19.
Petrol Rail Motor Coaches.* T. F. Charlton and H. Grinsted. (Paper read before the Inst. of Automobile Engrs.) (47) Jan. 19.
The Steel Passenger Cars in the Odessa Wreck on the St. Paul.* (15) Jan. 19.
New Seattle Terminals; Oregon-Washington Railroad & Navigation Company.* (15) Jan. 19.
1 000 B. H. P. Crude Oil Locomotive.* (47) Jan. 19.
The Use of Electricity for the Control of Railways. J. E. Sayers. (Abstract of paper read before the Derby Soc. of Engrs.) (73) Jan. 19.
Observation Cars for the Illinois Central R. R.* (18) Jan. 20; (15) Jan. 12.
Railway Construction in the Des Chutes River Country.* (18) Jan. 20.
Production of Ties. A. R. Joyce and A. Meyer. (Papers read before the Wood Preservers' Assoc.) (18) Jan. 20.
Wood Preservation and its Relation to the Central Electric Railway Association.* Frank P. Smith. (17) Jan. 20.
27-Ton Locomotive for the Guelph Radial Railway Company.* (96) Jan. 25.
Highly Superheated Steam for Locomotives.* Gilbert E. Ryder. (Paper read before the Southern and Southwestern Ry. Club.) (15) Jan. 26.
Electric Towing Locomotive for the Panama Canal Locks.* (15) Jan. 26.
Tests of Jacobs-Shupert Firebox. (18) Jan. 27.
Signal System at Pennsylvania Station, New York.* (19) Jan. 27.
The First Trans-Continental Railway in South America, from the Atlantic to the Pacific.* F. C. Coleman. (46) Jan. 27.
Ballasting with Lava Deposits. F. M. Siefer. (14) Jan. 27.
Mikado Locomotives for Heavy Freight Service.* (15) Feb. 2.
Construction of the Copper River & Northwestern.* (15) Feb. 2.
A Reinforced Concrete Locomotive Coaling Station.* (14) Feb. 3.
Mikado Type Locomotives for the Erie Railroad.* (18) Feb. 3.
Compagnie Impériale des Chemins de Fer Chinois Ligne du Tcheng T'Ai (Chansi). A. Millorat. (32) Nov.
Essais d'Eclairage avec Feux Clignotants aux Signaux Fixes des Chemins de Fer de l'Etat Suédois.* E. G. Windahl. (From *Teknisk Tidskrift*). (43) Nov.
Système de Ranchet Articulé Présenté par Jacquemain-Compas.* E. Sauvage. (92) Dec.
Les Avantages de la Surchauffe Modérée sur les Locomotives aux Etats-Unis.* (33) Dec. 30.
De la Fermeture des Brèches Produites sur la Ligne de Tours à Nantes par la Dernière Crue de la Loire.* G. Liébeaux. (38) Jan.
Anordnung und Abmessung der Schächte für Bahnsteig-Gepäckaufzüge.* Landsberg. (102) Dec. 15.
Gleisleg-Maschine von Hurley.* F. Bock. (102) Dec. 15.
Die Tunnel der neuen Untergrundbahnen in Newyork.* F. Bock. (102) Jan. 1.
Neue Lokomotivhalle der Hauptwerkstätte Stendal.* Simon. (102) Jan. 1.
Kugelachslager für Eisenbahnfahrzeuge. Schmid-Roost. (102) Jan. 15.
Entstäubungsanlagen für Personenwagen.* F. Zimmermann. (102) Jan. 15.

Railroads, Street.

A System of Transition Curves for Street Railways. C. W. L. Filkins. (36) Jan.
Semi-Steel Cars for the Boston Elevated Railway.* (17) Jan. 6.
Steel Cars for the Cambridge Subway.* (17) Jan. 13.
Tunneling in Sand for a Subway Crossing Under a Subway.* (13) Jan. 18.
Petrol-Driven Tramway Car.* (12) Jan. 19.
A New Type of Elevated Railway in Boston.* (14) Jan. 20.
Trailer Operation in Pittsburgh.* (17) Jan. 20.

*Illustrated.

Railroads, Street—(Continued).

Storage Battery Snow Sweepers with Anti-Friction Bearings.* (17) Jan. 20.
A Difficult Engineering Feat Carried Out in Paris, Piercing the Montmartre Hill for a Subway.* (46) Jan. 27.
Notes on the Wheeling Traction Company.* (17) Jan. 27.
The Cambridge Subway.* L. E. Moore. (13) Feb. 1.
Middletown Carhouse of the Connecticut Company.* (17) Feb. 3.
Equipment for 1 500-Volt D. C. Line of Piedmont Traction Company.* (17) Feb. 3.

Sanitation.

Disinfecting Miners' Dwellings. W. H. Ross and R. C. Benner. (103) Dec. 30.
Heating and Ventilating of the Pennsylvania Station.* George Gibbs. (70) Jan.
Heating and Ventilating a Village School.* (70) Jan.
Mechanical Furnace Heating and Ventilating System in the New School Building at Morgantown, W. Va.* (70) Jan.
Notes on the Theory and Practice of Percolating Filters. J. E. Farmer. (Paper read before the Assoc. of Mgrs. of Sewage Disposal Works at Croydon.) (96) Jan. 4.
Cost of Garbage Reduction. (96) Jan. 4.
Operating Results at the Columbus Sewage Works. (14) Jan. 6; (86) Jan. 17.
Sewage in Sea Water. E. A. Letts. (Abstract of paper read before the Royal San. Inst.) (14) Jan. 6.
Methods of Construction on the Cleveland Main Intercepting Sewer Between East 61st and East 79th Streets * Ivan A. Greenwood. (86) Jan. 10.
Acton Infectious Diseases Hospital.* Frederick Sadler, M. Inst M. and C. E. (104) Jan. 12.
Humidity and Ventilation in Cotton-Weaving Sheds.* (11) Jan. 12.
Results of Septic Tank Treatment of Sewage at Plainfield, New Jersey; Operating Data and Experimental Studies of the Liquefaction of Solids. Roy S. Lanphear. (14) Jan. 13.
Experiments with Contact Beds. (14) Jan. 13.
Coal Required to Heat Modern City Building.* E. F. Tweedy. (64) Jan. 16.
The Proper Disposal of Domestic Wastes in Rural Districts. John Brook. (Paper read before the Inst. of Mun. Engrs.) (104) Jan. 19.
Heating and Ventilation of Court House.* (101) Jan. 19.
The Imhoff Tanks and Sprinkling Filters at Holzwickede, Germany.* Charles Saville and Richard H. Gould. (14) Jan. 20.
Methods of Refuse Disposal for Toronto. Rudolph Hering and John H. Gregory. (Report to the City Council of Toronto.) (96) Jan. 25.
The Waterproofing of Sewers. (Abstract from paper read before the National Assoc. of Cement Users.) (96) Jan. 25.
The Madison-Chatham Sewage Disposal Works.* (14) Jan. 27.
Some Drainage Problems of Southern Illinois. J. G. Mosier. (Abstract of paper read before the Assoc. of Drainage and Levee Dists. in Ill.) (14) Jan. 27.
The Single Pipe System of Heating. William Kavanagh. (64) Jan. 30.
The Need of Well Considered Design and Efficient Operation of Sewage Disposal Plants.* Langdon Pearse. (Abstract of paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) Jan. 31.
Refuse Disposal in Cambridge, Mass. (60) Feb.
Heating and Ventilating 12-Story Club Building, New York Lodge No. 1, B. P. O. Elks.* (70) Feb.
Lethbridge Sewage Disposal Works.* (96) Feb. 1.
Laying Large Concrete Sewer Pipe with Machinery.* (14) Feb. 3.
Effect of Uniformity of Distribution in Sewage Filtration. (14) Feb. 3.
The Statement of a Problem in Sewage Purification Arising from the Neglect and Failure of a Septic Tank.* F. L. Stone. (Abstract of paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) Feb. 7; (14) Jan. 27.
Appareils Respiratoires à Oxygéne Comprimé avec Régénération de l'Air Expire.* Hector Denis. (34) Jan.

Structural.

Metallic Roofing. D. M. Buck. (58) Dec.
The Design of Tall Chimneys.* Henry Adams, M. Inst. C. E. (Paper read before the Soc. of Engrs.) (47) Dec. 29; (96) Feb. 1.
Pittsburg Pure Brand of American Uniform Ingot Iron. H. M. Feldman. (Paper read before the Am. Inst. of Steam Boiler Inspectors.) (94) Jan.
Cement Lumber.* (67) Jan.
Concrete Pockets Erected by Troy Firm. (Coal Pockets.) (67) Jan.
Prevention of Corrosion in Metal Lath. Clarence W. Noble. (67) Jan.
The Foundation Work for the Woolworth Building at New York City.* Charles S. Rindsfoos. (36) Jan.
Precautions to be Taken Before Concreting, and Concreting in Freezing Weather. Jerome Cochran. (36) Jan.

*Illustrated.

Structural - (Continued).

Mayari Steel: Its Properties and Uses.* (20) Jan. 4.
A Novel Gas-Holder Foundation.* Hunley Abbott. (13) Jan. 4; (24) Jan. 29.
Reinforced Concrete Stresses. Ernest McCullough. (13) Jan. 4.
Comparative Tests of Cement Gun Concrete and Hand Applied Concrete. (13) Jan. 4.
The Brinell Test for Automobile Steel. Denison K. Bullens. (20) Jan. 4.
Concrete Factories.* (96) Jan. 4.
Air Pressure on Inclined Plane Surfaces.* A. W. Johns, M. Inst. N. A. (11) Jan. 5.
Universal Joist Steel-Sheet Piling.* (11) Jan. 5.
An Economical Concrete Plant.* Edw. Cunningham. (13) Jan. 6.
Methods of Waterproofing Available for Various Structures and Costs of Various Waterproofing Processes. Myron H. Lewis. (Abstract of paper read before the Am. Soc. of Eng. Contractors.) (86) Jan. 10.
Detailed Methods Employed in Sinking and Converting Caisson Foundations in Chicago.* Chester B. Lewis. (86) Jan. 10.
An Erection Shop of Unit Reinforced Concrete.* (14) Jan. 13.
Analysis of Cylindrical Reinforced Concrete Chimneys. I. Oesterblom. (Abstract of paper read before the Am. Soc. of Swedish Engrs.) (14) Jan. 13.
Creosotes and Creosoting Oils. David Allerton. (Abstract of paper read before the Wood Preservers' Assoc.) (15) Jan. 15.
Creosote Specifications and Analysis. Hermann von Schrenk. (Abstract of paper read before the Wood Preservers' Assoc.) (15) Jan. 15.
Ilkeston Gasholder Disaster.* (66) Jan. 16.
Analysis for Moments in Continuous Beams of Non-Uniform Section.* S. Ingberg. (86) Jan. 17.
Regulations for Concrete Buildings, City of Cleveland, Ohio. (13) Jan. 18.
Reinforced Concrete in New York City; Regulations Adopted on December 28, 1911, by the Superintendents of Buildings of All Five Boroughs of the City. (14) Jan. 6; (13) Jan. 18.
Foundation Work in Montreal.* Alexander Allaire. (96) Jan. 18.
Various Features of Wood Preservation. (Abstracts of papers read before the Wood Preservers' Assoc.) (14) Jan. 20.
The Decay and Preservation of Timber. William Ransom, Assoc. M. Inst. C. E. (104) Serial beginning Jan. 26.
Constructing the Foundations of the Seamen's Church Institute, New York; Pneumatic Wall Caissons were Sunk Through Mud, Clay, Sand and Hardpan, Bonded Together and Braced Across the Lot. (14) Jan. 27.
A Reinforced Concrete Piano Warehouse. (14) Jan. 27.
Directions and Suggestions for the Inspection of Concrete Materials. Jerome Cochran. (86) Jan. 31.
Hardness of Plasters and Cements, and a Simple Chronographic Apparatus for Recording Set.* Chas. F. McKena. (Paper read before the Am. Inst. of Chemical Engrs.) (105) Feb.
Tests of Coal Tar Paint. (13) Feb. 1.
Proportioning Gravel Concrete.* Clifford Older. (Paper read before the Ill. Soc. of Engrs. and Surveyors.) (14) Feb. 3.
The Effect of Salt Impregnation on Timber.* (14) Feb. 3.
Raising Buildings in the Flood District, Pittsburg. (14) Feb. 3.
A Large and Deep Cellar Excavation in Earth and Rock.* (14) Feb. 3.
Résistance des Pieux Théorie et Applications.* J. Benabenq. (43) Nov.
Deuxième Note sur le Calcul des Poutres en Ciment Armé.* M. Pigeaud. (43) Nov.
Normes britanniques pour l'Essai et la Fourniture des Ciments. (84) Dec.
Constructions en Ciment Armé par Claveaux, Système Monnoyer.* (84) Dec.
Les Propriétés du Ciment Expliquées par sa Nature Colloïdale. (84) Dec.
Pieux à Vis pour Fondations, construit par la Société Anonyme de Baume et Marpent à Marpent (Nord).* (35) Jan.
Calcul des Dimensions et du Pouvoir Porteur des Pieux de Fondation.* Ch. Dantin. (33) Jan. 27.
Le Percement de la Rue des Italiens, à Paris, Groupe Immobilier de la Compagnie l'Urbaine-Vie.* A. Bidault des Chaumes. (33) Serial beginning Jan. 27.
Die wirtschaftliche Höhe einer Futtermauer.* Gaber. (81) Pt. 1, 1912.
Zur Theorie statisch unbestimmter Hauptsysteme.* K. Eisenmann. (81) Serial beginning Pt. 1, 1912.
Berechnung ebener rechteckiger Platten.* Hager. (51) Serial beginning Sup. No. 1.
Eisenbeton-Konstruktionen der neuen Kathedrale in St. Louis in den Vereinigten Staaten von Nord-Amerika.* (51) Serial beginning Sup. No. 1.
Der Kunstschluss im Tunnelgewölbe.* Gaber. (51) Sup. No. 2.
Zwei Kirchturm-Fachwerke aus Eisenbeton.* H. Frantz. (51) Sup. No. 2.
Die Einwirkung einiger Steinschutzmittel auf Sandstein. A. Behre. (49) Pt. 10, 1911.

*Illustrated.

Structural—(Continued).

Beitrag zur Berechnung dreifach statisch unbestimmter Systeme mit Hilfe von Elastizitätsgleichungen, die voneinander unabhängig sind.* Kirchoff. (49) Pt. 10, 1911.

Der Neubau der Königlichen Akademie in Posen.* (49) Pt. 10, 1911.

Praktische Beispiele zur Bewertung von Erddruck, Erdwiderstand und Tragfähigkeit des Baugrundes in grösserer Tiefe.* H. Krey. (49) Pt. 1, 1912.

Einfluss des Eisenbetons auf Konstruktion und Architektur beim modernen Hochbau unter besonderer Berücksichtigung auf Wiener Schul- und Kommunalbauten.* Ludwig Roth. (53) Dec. 29.

Die Wandelhalle auf der Insel Borkum.* Alfons Ritter. (78) Jan. 3.

Ueber den Knickwiderstand gegliederter Stäbe.* R. Saliger. (53) Serial beginning Jan. 5.

Die Neubauten des k. k. Allgemeinen Krankenhauses.* Barth. Piekniczek. (53) Serial beginning Jan. 5.

Ueber die magnetischen Eigenschaften von Nickel- und Manganstählen.* S. Hilpert, E. Colver-Glauert und W. Mathesius. (50) Jan. 18.

Ueber die Verwendung eiserner Formen für Betonbauten.* R. Hoffmann. (78) Jan. 18.

Ueber den Einfluss der Natriumphosphat- und boratlösungen auf den Portlandzement, insbesondere auf den Beton. Otakar Kallauner. (78) Jan. 18.

Der Höhe des Plattenbalkens der geringsten Kosten. Martin Preuss. (78) Jan. 18.

Die Eisenbetonkonstruktionen im Neuen Theater zu Frankfurt a. M.* E. Neugeboren, und J. Wickmann. (78) Jan. 18.

Einfluss der Höhe des Sandzusatzes auf die Festigkeit von Trasskalkmortel.* H. Burchartz. (80) Jan. 27.

Topographical.

Topographical Surveys on the Canadian Pacific Railway Irrigation Project.* (14) Jan. 13.

Water Supply.

The Flooding of the Approach End of a Culvert due to a Small Rise in the Level of the Water at the Outlet End.* John Goodman. (63) Vol. 186.

The Water Supply of Liverpool, England.* Kenneth C. Grant. (98) Dec.

Pure Water and its Relation to Health.* J. W. Ellms. (Paper read before the Detroit Eng. Soc.) (1) Jan.

Measurement of Water, Means Available and Their Relative Accuracy. Gardner S. Williams. (4) Jan.

Measuring the Flow of Water in Large Pipe Lines.* R. M. Hosea. (4) Jan.

Relining a Brick-Lined Reservoir.* Thomas Fleming, Jr. (36) Jan.

Failure of Austin Dam.* J. W. Ledoux. (2) Jan.

A Brief Description of Water Supply of the City of Syracuse.* Marshall B. Palmer. (36) Jan.

Sub-Tropical Drainage.* C. G. Elliott. (76) Jan. 1.

Irrigation by Pumping in New Mexico. Willard E. Holt. (Abstract of paper read at the National Irrig. Cong.) (13) Jan. 4.

Safe Velocities of Water on Concrete.* Arthur P. Davis. (13) Jan. 4.

An Excessive Run-Off from a Small Drainage Area near Hartford, Conn.* W. L. Butcher. (13) Jan. 4.

The Comparative Values of Water Power and Steam Power. A. C. Dunham. (27) Jan. 6.

A Hydroelectric Plant Equipped with a Novel Surge Tank.* (14) Jan. 6.

State Control of the Design of Dams and Reservoirs. Farley Gannett. (14) Jan. 6.

Construction on the Los Angeles Aqueduct, a Review of the Methods of Excavating and Concreting in Desert Land.* (14) Jan. 6.

A Survey to Detect Water Waste in Milwaukee. Ray Palmer. (Abstract of report to Commr. of Public Works.) (14) Jan. 6.

Changes and Operating Results at the Coagulation and Sedimentation Plant of the Water-Works of St. Louis, Mo.* Edward E. Wall. (13) Jan. 11.

Water Consumption and Waste, the Use of Meters and Meter Rates at Washington, D. C. (13) Jan. 11.

Irrigation by Pumping.* H. J. Kennedy. (Abstract from *Purdue Eng. Review.*) (96) Jan. 11.

Water Purification at Columbus, Ohio; Results at the Water Softening and Filtration Plant for the Year 1910. (14) Jan. 13.

Measuring the Water used in a 13 500 Horse-Power Turbine. (14) Jan. 13.

Test of a Small Concrete Arch.* (Filter arch.) (14) Jan. 13.

Further Development at Snoqualmie Falls, a Separate Generating Station Built to Supplement an Underground Plant to Which no Further Extension was Practicable.* Magnus T. Crawford. (14) Jan. 13.

*Illustrated.

Water Supply—(Continued).

Lawrence Experiment Station Studies in the Purification of Water. (86) Jan. 17.
A 200 000 Acre Drainage Project Calling for 14 000 000 Cu. Yds. of Ditch Excavation.* (86) Jan. 17.
The Estimation of Costs in Relation to Drainage Systems. J. L. Parsons. (86) Serial beginning Jan. 17.
Water Supply for Dallas, Texas.* Eugene Couch. (13) Jan. 18.
Removing the Old Standpipe in the Chicago Avenue Pumping Station: Chicago.* F. Carl Martini. (13) Jan. 18.
The Montreal Filtration Works. Frederick E. Field. (96) Jan. 18.
New Regulations Governing the Design and Construction of Dams, Issued by the New York State Conservation Commission, Alexander Rice McKim, Inspector of Dams and Docks. (14) Jan. 20.
How the Flow of Water through the Catskill Aqueduct will be Measured; a Description of the Three Largest Venturi Meters ever Constructed and Apparatus for Making Continuous Records of the Flow.* (14) Jan. 20.
Hydraulic Power at Shelburne Falls, Massachusetts. (14) Jan. 20.
Notes on Driving the Elizabeth Lake Tunnel. (14) Jan. 20.
The Longest Solid Concrete Structure in the World; Power Plant of Mississippi River Power Development Co., at Keokuk, Iowa.* Frank C. Perkins. (62) Jan. 22.
Cost of Pumping Plant and of Pumping Water for Irrigation, Minidoka Project, U. S. Reclamation Service.* (86) Jan. 24.
A New Process for the Separation and Grading of Solids Suspended in Liquids.* William J. Gee. (29) Jan. 26.
The Kachess Dam on the Yakima River in Washington. (14) Jan. 27.
The New Plant for the Purification of the Water Supply of Kansas City, Kansas. (14) Jan. 27.
The Possibilities of Power from the Tides; Results of Tests at Mamaroneck and a Discussion of Methods used Elsewhere.* J. Royden Pierce. (14) Jan. 27.
Diagrams for Determining Friction Loss in New Cast Iron Pipe. A. N. Talbot and M. L. Enger. (Abstract of paper read before the Illinois Water Supply Assoc.) (86) Jan. 31.
Reclaiming of Minnesota's Swamp Lands: General Statement of Problem and of Progress of the Work.* George A. Ralph. (86) Serial beginning Jan. 31.
Reinforced Concrete Gate Tower for the Morena Dam, San Diego, Cal., Water Supply.* (86) Jan. 31.
Catskill Aqueduct Control Valves.* James Owen. (13) Feb. 1.
Standpipe Failure at Sheboygan, Wis.* Jerry Donahue. (13) Feb. 1.
Ice Trouble at the Saint Louis Water Works.* Edward E. Wall. (13) Feb. 1.
Principles of Water-Power Development. W. J. McGee. (19) Serial beginning Feb. 3.
Savage Irrigation in Luzon.* Hamilton Wright. (46) Feb. 3.
Modern Water Coolers for Factories. (19) Feb. 3.
The Lord Water Softening Apparatus.* (18) Feb. 3.
New Hydroelectric Plant of Northern California Power Co.* Rudolph W. Van Norden. (27) Feb. 3.
Blasting Ice on the Wilmington Slow-Sand Filters. (14) Feb. 3.
Leakage in Cast-Iron Water Pipe. E. G. Bradbury. (Abstract of paper read before the Ohio Eng. Soc.) (14) Feb. 3.
Pipe Yard and Shops of the Reading Water Department.* Emil L. Nuebling. (14) Feb. 3.
Water Power on the Los Angeles Aqueduct, the Conditions Affecting Hydroelectric Development at Six Stations.* (14) Feb. 3.
Sinking an Open Well with a Clam-Shell Bucket.* (14) Feb. 3.
The South Haiwee Earth Dam and Reservoir of the Los Angeles Aqueduct; Earth Fill Delivered in Dump Cars, Jetted to Place by Nozzle Streams. J. B. Lippincott. (14) Feb. 3.
Data on Pumping Machinery for Land Drainage with Examples of Pumping Plants.* S. M. Woodward. (Abstract from Bulletin. No. 243, U. S. Office of Experiment Stations.) (86) Feb. 7.
Fabrication des Tuyaux en Ciment.* E. Bazin. (35) Serial beginning Jan.
Die Wasserkräfte Schwedens und ihre Ausnutzung.* E. Mattern. (49) Pt. 10, Geschwindigkeit. M. Graevell. (81) Pt. 1, 1912.
Die Wasserkräfte Schwedens und ihre Ausnutzung.* E. Mattern. (49) Pt. 10, 1911.
Ueber ausgeführte Gewölbe—Talsperren in Neusüdwales, Berechnung, Rissbildungen, Durchbiegungsmessungen.* Ziegler. (78) Serial beginning Jan. 3.
Hydraulische Druckregulatoren.* R. Dubs und A. Utard. (107) Serial beginning Jan. 6.
Wasserbehälter in Victoria (Australien).* Essling. (78) Jan. 18.
Die Neuanlagen des Bürgerlichen Bräuhauses in Pilsen.* Franz Spalek. (53) Serial beginning Jan. 19.

*Illustrated.

Waterways.

Light Reinforced-Concrete Wharfing used in the Port of Madras.[1] Francis Joseph Edward Spring. (63) Vol. 186.
Steel Sheet Pile Retaining Walls (Seawall).* Myron H. Lewis. (13) Jan. 4.
The Marine Terminal of the Grand Trunk Pacific Ry., Prince Rupert, B. C.* Frank E. Kirby and William T. Donnelly. (13) Jan. 4.
River Waters of the United States.* (U. S. Geol. Survey, Water Supply Paper No. 236.) (104) Jan. 5.
The Latest Municipal Pier at Philadelphia; Pier No. 19, Built of Concrete and Steel.* (14) Jan. 6.
Driving Reinforced Concrete Piles into Coral Formation. (14) Jan. 6.
Building the Panama Canal.* (101) Jan. 12.
Electric Power for the Panama Canal.* John Geo. Leigh. (26) Serial beginning Jan. 12.
Submerged and Shore Lands of Illinois, a Review of the Findings of the Committee. (14) Jan. 13.
Reinforced Concrete Lumber Wharf for the Panama Railroad: Methods of Sinking Concrete Caissons and Progress of Construction.* (86) Jan. 17.
The Great National Port of Canada.* Frederick W. Cowie. (96) Jan. 18.
The Mississippi River Lock and Dam No. 1.* (14) Jan. 20.
Comparison of Plant and Operating Cost of Day Labor and Contract Work in the U. S. Improvement of the Upper Mississippi River.* Charles W. Durham. (86) Jan. 24.
The Kansas City Municipal Wharf.* Clark R. Mandigo. (13) Jan. 25.
Last Stages of the Panama Canal Construction.* (12) Serial beginning Jan. 26.
Great Northern Ore Loading Dock at Allouez, Wis.* (15) Jan. 26.
A Concrete Pier at Oakland.* (14) Jan. 27.
A Concrete Lighthouse. (14) Jan. 27.
Methods of Embankment Protection.* (Paper read before the Am. Ry. Bridge and Bldg. Assoc.) (18) Jan. 27.
Erecting Lock Machinery at Panama Canal.* (62) Jan. 29.
Mechanical Appliances on the Panama Canal.* J. F. Springer. (10) Serial beginning Feb.
Etude du Projet "Clichy-Port-de-Mer." Ch. Lavaud. (32) Nov.
Les Travaux d'Amélioration du Rhone.* Armand. (43) Nov.
Observations Faites sur la Seine à Paris pendant la crue de Janvier-Février-Mars, 1911. M. Arana. (43) Nov.
Hafenbauten aus Eisenbeton in Norwegen.* (78) Jan. 3.
Der Entwurf eines preussischen Wassergesetzes. (51) Serial beginning Jan. 3.
Der neue Grossschiffahrtkanal im Staate New York. Michael J. Nagel. (53) Jan. 5.
Die Kanalisierung der unteren Bega.* Ign. Pollak. (53) Jan. 26.

*Illustrated.

Vol. XXXVIII. FEBRUARY, 1912. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

CONTENTS

PLATES

For Index to all Papers, the discussion of which is current in *Proceedings*, see the end of this number.

Vol. XXXVIII. FEBRUARY, 1912. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

REBUILDING THREE LARGE PUMPING ENGINES.

By Charles B. Buerger, Assoc. M. Am. Soc. C. E.

To be Presented March 20th, 1912.

The Queen Lane Pumping Station, at Wissahickon, on the Schuylkill River, Philadelphia, was equipped in 1895 and 1896 with four single-acting, vertical, triple-expansion, crank-and-flywheel, pumping engines, built and installed by the Southwark Foundry and Machine Company, of Philadelphia. Some of the principal dimensions of these engines were as follows:

Rated capacity	20 000 000 gal. per day.
Speed	22 rev. per min.
Stroke	54 in.
Plunger, diameter	34½ in.
High-pressure cylinder, diameter	37 in.
Intermediate-pressure cylinder, diameter	62 in.
Low-pressure cylinder, diameter	96 in.
Piston rod, diameter—two to each cylinder	5¼ in.
Distance rod, diameter—4 to each pump	5 in.
Main journal, diameter	18 in.
Main journal, length	28 in.
Crank-pin, diameter	12 in.
Crank-pin, length	9 in.
Cross-head pin, diameter	13 in.
Cross-head pin, length	10 in.
Flywheel, diameter—two to engine	17 ft. 9 in.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Suction and discharge pipes............	48 in.
Valve area per suction deck............	801 sq. in.
Valve area per discharge deck..........	801 sq. in.
Total water pressure..................	246 ft.
Steam pressure........................	150 lb. per sq. in.

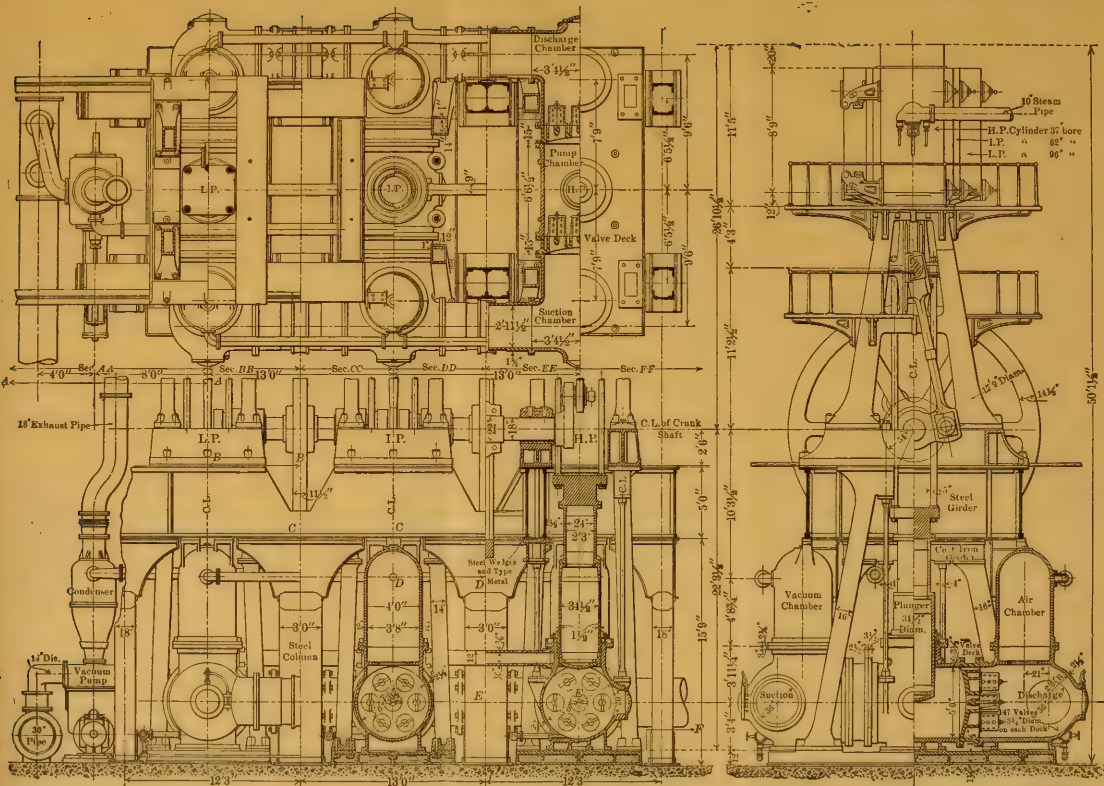
The contract price for the four engines in place was $294 148, which is low when compared with the present-day cost of four engines of the same capacity; but, taking into account the difference in weight and materials, the price was very fair.

The design, in some respects, was in accordance with accepted practice, and in other respects unusual. The steam end was of the double A-frame type, built generally, as is common to-day, except that the steam distribution valves, instead of being of the usual Corliss construction, were of the gridiron design, and operated through a cam motion by eccentric rods on the main shaft. The steam end was carried from the basement floor by a structural steel framework, consisting of eight box-columns in two lines, carrying two longitudinal plate girders, and four transverse, double-web box-girders, one under each main bearing. The arrangement of the steam end and supporting steel structure is shown on Plate X, which is a drawing of the rebuilt engine.

The pump end under each steam cylinder consisted in effect of three cylindrical chambers, placed one over the other, the lowest carrying the suction valve deck, the middle one an annular flat discharge valve deck, and the upper one a stuffing-box for the vertical plunger. The three sections were bolted together, the lowest to the foundation and the top one tied to the steam bed-plate by four steel bolts.

The pumping engines were unsatisfactory in operation from the time of earliest service. The structural steel framework was not braced to give sufficient rigidity to the steam end, and the vibration rapidly wore out all the wearing parts, resulting in misalignment and frequent breakages. The water end was even less satisfactory; the shapes of the castings were unsuited to the service, and some as thick as 4 in. lasted but a short time; the pumps, too, were insufficiently braced, vibration made the joints leak, and air reduced the pump deliveries.

The four engines were kept in regular but inefficient service, at the cost of heavy repairs, until 1907, when the introduction of a filtered



QUEEN LANE PUMPING STATION
REBUILT PUMPING ENGINE
GENERAL PLAN

water supply from another city plant permitted a partial shut-down of the station. In 1908 it was decided to build an additional filter station at the Queen Lane Reservoir, which would demand a regular supply of 70 000 000 gal. per day; the location of the proposed filter station, its elevation, and the pipe connections already in service to the Queen Lane Pumping Station, called for a water supply from this place, and it was necessary to make changes to put the machinery into effectual operation. New engines were estimated to cost, erected, about $100 000 each, and these could be expected to give a duty of 155 000 000 ft-lb. per 1 000 000 B. t. u. with the available steam pressure of 140 lb.

The reconstruction of the old engines was estimated to cost $175 000 for the four engines, about $44 000 each; they would then be capable of giving a duty, based on their performance in 1896, of about 140 000 000 ft-lb. per 1 000 000 B. t. u. The saving in installing new and more economical machinery would be, in round numbers, $2 000 per year in fuel—insufficient to warrant the additional expenditure. The plan of retaining the old machines in service and rebuilding them was accordingly adopted.

The alteration of any completed and used work is always full of complications and difficulties, markedly so where used machinery is in question. The common course in such case is to make a contract for a lump sum for the completed reconstruction, according to specifications based on the results sought. The writer, in charge of this work for the Philadelphia Bureau of Water, found this course, though easy, highly objectionable. Primarily, there could be no competition for work of this character, as manufacturers do not care to compete with the original builder of an engine for such a contract, so that bidding in this way means but a single proposal, and this cannot be expected to be a low one. Then, the difficulties of estimating on such work intelligently are considerable, and a losing contract is a temptation to the contractor to slight the work. The writer has a case in mind where a reputable manufacturer undertook, at an apparently generous price, to rebuild one of his old engines; after he had done some work on it and was able to appreciate what he had before him, he offered to abandon the old material entirely and to furnish in place an entirely new machine of the same capacity at his bid price. Lastly, and of most importance, it is impracticable to foresee exactly what will be required, and to call for the items explicitly, and if

dependence is placed on broad specifications, disputes will arise in the execution of the work which cannot easily be adjusted equitably.

The unit-price contract presented the only plausible alternative.

Specifications.

The work was advertised on a brief specification for one engine. The following are the more important paragraphs:

(1) *Work to be Done.*—The work to be done consists of furnishing and delivering the material for rebuilding the pump ends of one vertical pumping engine at the Queen Lane Pumping Station, together with all appurtenances, and the delivery of one air pump.

(2) *Contract Plans.*—The following plans show the general design to be followed: Sheet No. 1.—Side elevation and sections; Sheet No. 2.—End elevation and sections.

(3) *Detail Plans.*—The City will furnish all detail plans for the work.

(4) *Patterns.*—The Contractor shall build all necessary patterns for the entire work; these patterns shall become the property of the City, and, on the completion of the work shall be delivered to the City shops. All flange drilling shall be done from approved jigs, which shall likewise become the property of the City, without extra charge.

(5) *Basis of Award.*—The following quantities shall be used in comparing bids:

Item	1-*a*	Cast iron—all kinds	600 000 lb.
"	1-*b*	Cast steel—all kinds	35 000 "
"	1-*c*	Forgings, steel and wrought iron	35 000 "
"	1-*d*	Bolts, nuts, and washers	15 000 "
"	1-*e*	Composition—all kinds	6 000 "
"	2	One air pump, delivered	Lump sum.

(6) *Character of the Work.*—All castings, forgings, etc., shall be machined to the dimensions shown on the detail plans, and in finish shall equal the present best practice. All work shall be fitted together and erected in the shop.

(9) *Variation of Weights.*—Payment for castings will be made on the basis of actual weights delivered; except that the weight paid for shall in no case be more than 5% in excess of the calculated weight. Castings weighing less than within 8% of the calculated weight, or at any point not within 10% of the designed thickness, will be rejected.

The following are the specifications for the materials:

(*19*) *Painting.*—All castings and other details shall be inspected and approved before painting. All metal work not finished shall receive two coats of paint. All finished surfaces shall be coated with white lead and tallow.

(*20*) *Shop Test.*—All castings shall be subjected to a shop test of 300 lb. per sq. in., hydraulic pressure.

(*21*) *Time of Completion.*—The Contractor shall begin work under this contract within 10 days from the time of notice to begin work, and shall prosecute the work with diligence, and to the satisfaction of the Engineer.

(*22*) *Payments.*—Payments, in all cases, will be made at the unit prices bid, which are to include the delivery of the material in the Queen Lane Pumping Station, ready for final erection.

The contract for this engine was awarded to the I. P. Morris Company, of Philadelphia, at the following prices:

Cast iron	$0.0440	per lb.
Cast steel	0.0800	" "
Forgings	0.0825	" "
Bolts, nuts, and washers	0.0850	" "
Bronze and composition	0.5600	" "

Work was begun on May 22d, 1908; the first engine was completed and put into service on July 14th, 1909, a total elapsed time of 418 calendar days. Two additional engines have been similarly rebuilt, the time required for each being approximately one year.

The costs for the three units have varied somewhat, particularly for the repair work on the steam end. The average cost for one engine is approximately as follows:

Cast iron	450 230 lb.	$19 810.12
Cast steel	45 430 "	3 634.40
Forgings	9 596 "	791.67
Bolts, etc.	18 596 "	1 611.26
Composition	3 496 "	1 957.76
Steam end repairs, including material and labor		11 000.00
Air pump		1 370.00
Erection, labor (estimated)		4 000.00
Total		$45 015.21

Design of the Pump.

Plate X shows the general assembly and some details of the construction.

Framework and Columns.—The structural steel framework supporting the old steam ends was inspected carefully and found to be in excellent condition; the rivets, with few exceptions, were tight, and the joints solid. The vibration to which it had been subjected, while severe enough to disable the machinery, had left the steelwork uninjured. As a measure of economy, the steel frame was retained in place, loose rivets were replaced, and the columns were solidly bolted down and grouted. Under each steel box-girder supporting a main bearing was placed a pair of cast-iron columns, battered in two directions, resting on the pump bed-plate at the bottom, and at the top connected by a cast-iron strut and girder. This cast-iron girder was erected ½ to ¾ in. below the old steel girder, and was separated from it by steel wedges, 2 in. wide, at about 12-in. centers, driven into place solidly. The top flange of this girder was bolted to the lower angles of the steel by 1-in. bolts 12 in. apart, and the space between the two was filled with type metal.

As the columns were needed only as a bracing, they were made as light as it was practicable to cast them, of box section, 1 in. thick for the short columns, and 1¼ in. thick for the long columns, at the outside supports.

The cast-iron girders weigh 3 000 lb. each, the short columns 3 600 lb., and the long columns 6 900 lb.

Base-Plates.—A cast-iron base-plate was placed under each pump end. The base-plate has no structural value, and is of little value, except as warranted by the requirements of convenience in erection. It permits of locating and leveling the members, once for all; that is, four bracing columns, the pump chamber, and the suction and discharge chambers. It is of such a size as to connect all these, 12 in. deep, and generally 1½ in. thick. Both top and bottom surfaces are planed. The weight of each plate is 24 000 lb.

It is interesting to note that the first plate cast showed a bend of 1½ in. in cooling, the rough casting having the middle of the length that much lower than the line connecting the two ends. A bend in the pattern corrected this in subsequent castings.

Arrangement of Pump Ends.—The pump end is arranged in what is commercially known as the direct-flow type; the suction valves are on one side and the discharge valves at the other side of the pump chamber. The name is to some extent deceiving, as there is no reason to believe that the actual flow of the water is any more direct, or that the hydraulic resistance is even a little less, than in other arrangements not so well favored in name. This arrangement, however, permits a very satisfactory location of suction and discharge air chambers, both directly at the connection with the pump chambers. The writer considers this position of air chambers of decided advantage, and adopted the direct-flow type for this reason.

Pump Chambers.—The pump chamber is a T-shaped casting, 60 in. in diameter, and 3 in. thick. The corresponding stress in the body of the chamber is 1 000 lb. per sq. in., under working conditions. The allowed stress is apparently low, but is necessitated by the condition of intermittent and regularly repeated variations of pressure from a little lower than the suction, to a little higher than the discharge, pressure.

A comparison with some other pumps is made in Table 1.

TABLE 1.—COMPARISON OF PUMPS.

No.	Builder.	Date.	Style.	Capacity, in millions of gallons per day.	Working stress in pump chamber.
1	Southwark Foundry and Machine Company	1894	Horizontal, double-acting.	12	1 110
2	Henry R. Worthington	1901	Duplex, horizontal, double-acting	5	1 260
3	Holly Manufacturing Company	1901	Horizontal, double-acting, Gaskill	10	1 370
4	Holly Manufacturing Company	1907	Vertical, triple, single-acting	20	1 100
5	Allis-Chalmers Company	1907	Horizontal, double-acting.	6	1 100
6	Snow Steam Pump Company	1908	Horizontal, double-acting.	7½	1 370
7	Bethlehem Steel Company	1909	Horizontal, double-acting.	15	2 100 (cast steel)
8	City of Philadelphia	1909	Vertical, triple, single-acting	20	1 000

The critical points in a pump chamber are at the outlet openings for heads, manholes, and plungers. Where possible, it is desirable to round these with a curve of long radius, and also to thicken the metal,

in order to get the necessary resistance. This detail is shown in the longitudinal section of the pump chamber. Where such construction is undesirable because of the formation of air pockets, as at the plunger outlet of a vertical pump, a shrink bolt can be added to advantage. In this design, a $3\frac{1}{2}$-in. steel bolt is used at each side of the plunger opening, tightened up when hot, and stressed in cooling to its elastic limit.

Any exact determination of the stresses at such a corner is not to be expected, as these will vary from a maximum at the corner to a low figure some distance away; and it often happens that, even when the average stress through the section figured as a whole is very moderate, the shapes of the casting are such that unreasonably high stresses are imposed locally, and the casting will fail, though there is a sufficient weight of metal to do the work if it were disposed more judiciously.

For the purpose of comparison, the writer assumes that a stress figure can be obtained, by assuming that the corner forces are exerted uniformly over the length of curved section, and extending beyond the curve a length of three thicknesses of metal. Where a flange intervenes in this distance of three thicknesses, the metal outside the body line is not included. It is recognized that the maximum stresses at some points may be several times the quantity thus obtained. The method gives credit to easy curves, lower average stresses being obtained for curves of long radius; and conversely, straight sections are assumed to reinforce to only a limited extent, the length being proportionate to the thickness; flanges are supposed to be useful only for resisting the bolt strains. Qualitatively, these assumptions are undoubtedly correct, though the weight given is inexact.

On this basis, a comparison of the stresses in some of the pumps in Table 1 is given in Table 2.

TABLE 2.—Comparison of Stresses in Pump Cylinders.

Reference number, from Table 1.	Builder's name: and size of pump.	Corner stress, in pounds per square inch.
4............	Holly—20 000 000 gal. per day........	1 840
5............	Allis—6 000 000 " " "	930
6............	Snow—7 500 000 " " "	1 640
7............	Bethlehem—15 000 000 gal. per day....	2 100
8............	Philadelphia—20 000 000 gal. per day (neglecting shrink bolt)...........	1 260

While this method of calculation is arbitrary, it is of some value when taken in connection with Table 2, which shows some successful modern practice. The writer is familiar with many examples in practice which, on the standard of computation here given, show abnormally high stresses; he is also familiar with many cases of failure of such examples; and one failure is more instructive than a multitude of apparent successes. The weight of the pump chamber is 20 000 lb.

Stuffing-Box.—The stuffing-box is of bronze, fitted in the customary manner. The first packing used was hemp rings, $1\frac{1}{8}$ in. square, placed in single rings and separated by brass spacers to keep the packing in proper shape. This is the most common form for pumps of this type, and is satisfactory for clean water. For the muddy and gritty water pumped at this station, the hemp packing was a failure. Good service has been obtained since by a semi-metallic packing consisting of wedge-shaped, white metal, wearing rings held in place against the plunger surface by hemp fillers between. This packing has the particular advantage that it has no tendency to hold grit against the plunger surface and thus cut it.

Connecting Bolts.—The connecting bolts for the flange joints are $1\frac{1}{2}$ in., faced under the heads and under the nut, in spot-faced holes, $1\frac{19}{32}$ in. in diameter, spaced generally at about 5-in. centers. The bolts are designed for a maximum stress of 5 000 lb. per sq. in.

Gaskets.—The gaskets are of canvas, sewed into rings 3 in. wide, and painted with coal-tar. The flange joints are male and female. It is rather more common to use for this service gaskets made of rings of heavy paper soaked in linseed oil or red lead. This latter gasket is sufficient where the surfaces are perfect and the bolts are conscientiously tightened up until solid; but, where any surface may be slightly imperfect, or the bolts may be allowed to loosen, the tarred canvas joint is safer, as it will allow some water to blow through until the leak is detected, without destroying the gasket and compelling replacement.

Tension Rods.—The pressure of the plunger against the pump chamber is carried directly back to the steam end bed-plate by four steel tie-rods, 4 in. in diameter, giving a working stress of 2 000 lb. per sq. in. A low unit stress is here necessary to prevent a yield which would transfer the forces to the valve decks and discharge chambers. Such an arrangement is not unusual, and the castings are stiff enough

to serve, but it is probably preferable not to put these bending strains through the flange joints. The weight of each tension rod is 530 lb.

Valve Decks, Cages, and Valves.—The valve deck is of cast steel, a dome-shaped plate, 2 in. thick, dished to a 7-ft. radius, and set into a pipe, 60 in. in diameter, 2 in. thick, and 15 in. long. It has seven 13½-in. round openings, and is ribbed around these waterways, to add stiffness and to compensate for the metal removed. Each opening has a knife-edge cross-bar, carrying a 1¾-in. Parson's bronze stud, with thread 2 in. in diameter to hold the valve cage. The valve deck is designed for a maximum unit stress of 2 000 lb. per sq. in.

The valve is a screw-valve with a brass seat, outside size 3½-in. thick, carrying three valves on each side and three on the end. The use of steel for the cages caused a little extra cost for machine work, but there was no difficulty in making the castings.

The valve is screw-valve with a brass seat, outside size 3½-in. pipe thread, with four ribs, and ⅞-in. stem, using 3¾-in. by ⅝-in. rubber valves. The waterway of each valve is approximately 6 sq. in., and the designed pressure of the rubber valve on the seat is 200 lb. per sq. in. The spring is five turns of No. 8 phosphor-bronze wire, arranged for a lift of $\frac{9}{16}$ in., and with a resistance of ½ lb. per sq. in. of valve surface. Valves of two types were used, one with the valve stem cast integral with the seat, and the other with the stem screwed into the seat with a taper thread. The former type has given much the better service.

The weights are:	Valve deck....................	6 300 lb.
	Valve cage....................	180 "
	Valve seat, stem, etc............	1 "

The valve area per deck is 903 sq. in., giving a water velocity of 3.4 ft. per sec. at nominal rating.

Suction and Discharge Chambers.—The suction or discharge chamber (these are interchangeable) is a globe-shaped T with a top outlet for the air chamber. The body is 60 in. in diameter, and 2½ in. thick, giving a working stress of 1 200 lb. per sq. in. At all openings the thickness is increased the same as at the pump chamber openings; and, at the air chamber outlet, a diaphragm is cast with a 24-in. hole to reinforce the shell.

There is some apparent waste of material in making the suction

castings as heavy as the discharge castings, though ordinarily subjected to no pressure; but, in pumps for moderate pressures, such as this one, the possible reduction of weight, while keeping enough metal for rigidity, is not very great. The weight of this casting is 17 000 lb.

Air Chambers.—The air chamber for the suction or discharge end, is 44 in. in diameter, and 2 in. thick, giving a working stress of 1 100 lb. per sq. in. The top of the air chamber is fastened to the steel girder above by bolting through a cast-iron block fitted to the space left, and it helps to stiffen the steel frame. The weight of the air chamber is 7 300 lb.

The relation of the volume of air chambers provided to the capacity and type of pump is of interest. This relation is often a matter of judgment based on experience, rather than of numerical computation, and is affected by questions of structural convenience and patterns available, but a comparison based on a logical theory will to some extent indicate what this experience has determined.

There are two important standards for determining air chambers: one is dependent on the relation of the variable quantity of discharge of the pump as a whole to the flow in the suction or discharge lines, which is usually at practically constant velocity; the second is dependent on the relation of the variation of discharge of a single plunger to the air chambers effectual in absorbing the variable effect of the single plunger, and transmitting a constant effect to the pipe lines, or the suction or discharge chambers.

Considering first the pump as a whole in relation to the line: In the Queen Lane engine, as in any single-acting type, with cranks placed at 120° from each other, assume the pipe-line velocity to be constant:

Let A represent the area of the plunger,
S " " stroke,
N " " revolutions per minute,
a " " angular displacement of the crank,
Q " " the average rate of discharge of the whole pump (3 plungers),
T " " the time, in seconds,
E " " maximum excess of the water quantity delivered by the three plungers compared to the mean,
V " " plunger velocity,

Neglecting the effect of the angularity of the connecting rod, the elementary discharge in the time, dT, is

$$Q\,dT = \frac{3\,A\,S\,N\,dT}{60} \qquad (1)$$

The discharge of one plunger, which acts alone during the time of excess discharge, is

$$A\,V\,dT = \frac{A\,\pi\,S\,N\,\text{sin.}\,a\,dT}{60} \qquad (2)$$

The elementary variation in volume of the excess water is

$$dE = \frac{A\,\pi\,S\,N}{60}\,\text{sin.}\,a\,dT - \frac{3\,A\,S\,N\,dT}{60} \qquad (3)$$

$$= \frac{A\,S\,N}{60}\,(\pi\,\text{sin.}\,a - 3)\,dT \qquad (4)$$

and, as the angular velocity is

$$\frac{dA}{dT} = \frac{2\,\pi\,N}{60} \qquad (5)$$

$$dE = \frac{A\,S}{2}\left(\text{sin.}\,a - \frac{3}{\pi}\right)da \qquad (6)$$

To determine the limits between which an excess discharge takes place, put dE equal to 0

$$\frac{A\,S}{2}\left(\text{sin.}\,a - \frac{3}{\pi}\right)da = 0 \qquad (7)$$

$$\text{sin.}\,a = \frac{3}{\pi} \qquad a = 72^\circ\ 44' \ \text{and}\ a = 107^\circ\ 16'$$

$$E = \int_{72^\circ\ 44'}^{107^\circ\ 16'} \frac{A\,S}{2}\left(\text{sin.}\,a - \frac{3}{\pi}\right)da \qquad (8)$$

$$E = \frac{A\,S}{2}\left(-\,\text{cos.}\,a - \frac{3\,a}{\pi}\right)_{72^\circ\ 44'}^{107^\circ\ 16'} \qquad (9)$$

$$= 0.00926\,A\,S \qquad (10)$$

Call M the volume of the air chambers,

and p the ratio of variation of pressure to the original pressure,

$$p = \frac{0.00926\,A\,S}{M} \qquad (11)$$

For a two-cylinder, double-acting engine, with cranks at 90°,

$$E = 0.042\,A\,S \qquad (12)$$

A comparison of the engines in Table 2, on this basis, is given in Table 3.

TABLE 3.—COMPARISON OF E, M, AND p.

Reference No.	Make and size.	E	M	p
4	Holly—20 000 000 gal. per day..........	521	618 000	0.00085
5	Allis—6 000 000 " " "	425	100 000	0.0042
6	Snow—7 500 000 " " "	365	118 000	0.0031
7	Bethlehem—15 000 000 gal. per day......	715	304 000	0.0024
8	Philadelphia—20 000 000 gal. per day....	468	394 000	0.0012

Based on the second standard of comparison, the relation of the discharge of a single plunger to the air chambers effectual in absorbing the variable effect of the plunger discharge, in engines such as exemplified in Table 3, an air chamber is placed over each valve deck, all connected by the equalizing air pipes, so that the whole volume of all the air chambers acts to smooth the intermittent action of each single plunger, the variation in volume of air owing to other plungers being negligible.

The variable effect to be absorbed by the air chambers is directly proportional to the quantity of water discharged by that plunger, and to the maximum or average velocity of the plunger (these having a constant relation); using K to express the relative effectiveness of the air chambers, while V represents the mean plunger velocity.

$$K = \frac{M}{A\ V}$$

Table 4 is a comparison of the engines in Table 3 on this basis.

TABLE 4.—COMPARISON OF V AND K.

Reference No.	Make and size.	V	K
4	Holly—20 000 000 gal. per day...........	3.67	196
5	Allis—6 000 000 gal. per day..............	2.92	139
6	Snow—7 500 000 gal. per day..............	4.67	122
7	Bethlehem—15 000 000 gal. per day......	5.33	161
8	Philadelphia—20 000 000 gal. per day....	3.30	124

The agreement shown by the factor, K, in four of these engines is reasonably satisfactory; in Engine No. 4 the size of the air chambers is largely determined by structural considerations, and is probably not an intentional feature of the design.

Plunger.—The plunger is a closed-end pipe, $34\frac{1}{2}$ in. in diameter and $1\frac{1}{2}$ in. thick; the weight is 4 300 lb. The closed end is almost flat, being dished only enough for rigidity, as it is believed that the pointed end is of little value for a plunger running at this slow speed.

Repair Work on the Steam End.—The entire steam end was rebuilt, using the old parts merely as raw material, but re-machining and refitting all parts. The greater part of this work was only the routine of the machine shop, but a few points of interest are to be noted.

Steam Bed-Plates.—The old steam bed-plates carrying the main bearings were retained. In addition to being bolted to the steel frame, each bed-plate was fastened to the cast-iron girder at the tops of the bracing columns by six $2\frac{1}{2}$-in. bolts at each main bearing. The engines had originally but two such bolts, but their length, about 8 ft., and the insufficient stiffness of the bed-plate, permitted the bearings to lift, and required the addition of the four extra bolts. In the light of present experience, the steam bed-plates and the structural steel frames might have been abandoned and new bed-plates provided at no heavy increase in cost.

Main Shaft.—The drag-crank connection, in this type of crank shaft, is the sore thumb of the modern pumping engine. In this old machine, a ball joint with wedge adjusting plates had been provided originally. It was enlarged from 7 to 9 in. (for the 18-in. shaft), and made of high-carbon steel, with hard bronze wearing plates.

The writer is familiar with some of the drag-crank constructions provided in the best modern pumping engines, and considers them invariably insufficient. They are usually designed on the assumption that as there is little or no movement, the governing factor—the only important factor—is structural strength. It is the same mistake (but much more serious) as that made in designing pins for a pin-connected truss. A drag-crank connection should be built on the same lines as a bearing, with moderate unit pressures, and, particularly, with just as efficient a provision for lubrication. The attempt to provide a universal motion in such a style gives a cumbersome and expensive construction, but nothing less will serve.

Main Bearings.—In engines of this type, there seems to be a strong tendency of the shaft and the crank-pin forces to lift the main bearing caps, presumably by stretching the bolts. In these rebuilt engines, the cap is held down by four 3-in., and two $2\frac{3}{4}$-in. bolts, of 80 000-lb. steel; there is a noticeable amount of lift at the beginning of the upward stroke, more marked at the high-pressure end. The maximum steam cylinder force, in round numbers, is 100 000 lb., giving a bolt stress of 3 200 lb. per sq. in. Bolts have broken without showing any internal

defects. This corresponds to a similar condition observed by the writer in some recently built engines of the same size and type, of first-class construction, where four $3\frac{1}{2}$-in. bolts are used for the main bearing cap. Here, too, in some cases, the main cap will lift. This condition will obtain at times when the most careful measurements indicate with reasonable certainty that there is no misalignment of the bearings. It would be expected that bolts stressed to about 3 000 lb. would hold the cap with rigidity and safety. The writer would welcome any light which other members could throw on this subject.

Receivers.—In this reconstruction, the reheating tubes in the steam receivers were removed, and the receiving tanks were used merely as equalizers and separators. It was anticipated that, under the most favorable conditions, the possible gain in reheating would be trifling, and that in service a loss would be more likely than a gain.

Subsequent tests made at the Lardner's Point Pumping Station, in Philadelphia, with a number of identical Holly engines, have confirmed the correctness of this view. At that station, the best record of six engines, amounting to a duty of more than 182 000 000 ft-lb. per 1 000 lb. of wet steam, was made with the reheating coils cut entirely out of service.

A-*Frames.*—The erection of the A-frames developed the fact that it was necessary to converge the two frames of the steam cylinder at the steam end to allow for the expansion of the cylinder on admitting the steam. The final working lines of the hot engine then showed the guides to be parallel.

Exhaust Line.—The exhaust line between the low-pressure cylinder and the condenser was provided with an expansion joint just above the condenser, the line hanging from the cylinder. This is not usually considered necessary, but it is a precaution which is worth while.

Air Pump.—The first of the three engines was fitted with a direct-acting, steam-operated, air pump, as shown in Plate X; as the exhaust steam ran to the heater line, it was efficiently utilized, and the engine was simplified. The air pump was a standard commercial pump, built of poor material, and of flimsy design, and by breakages caused more trouble than all the rest of the engines. The second and third engines were fitted with air pumps driven directly from an extension arm from the low-pressure plunger cross-head.

The execution of the work, on the basis of unit price contracts, has

been simple and convenient, and the completed engines operate in a satisfactory manner. Such weak points as have developed have occurred in the steam end at places where structural limitations prevented any material change of design.

The Director of Public Works, Philadelphia, was Mr. George R. Stearns; the Chief of the Bureau of Water was Fred. C. Dunlap, M. Am. Soc. C. E.; and the work was in charge of the writer. The erection was done by the regular mechanical force of the Bureau, successively under Mr. James Barbour, and Mr. Harry Mellen, the plans having been drawn by Mr. W. E. Kuen. The contractors were the I. P. Morris Company, and the Southwark Foundry and Machine Company, both of Philadelphia.

Acknowledgment is due to Mr. Dunlap for permission to use the data contained in this paper.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

RETRACEMENT-RESURVEYS—COURT DECISIONS AND FIELD PROCEDURE.*

Table 2 has been compiled for the use of field engineers and surveyors, to enable them to make use of the different formulas for solving for azimuth, latitude, hour angle, and different functions of Polaris, without consulting so many books and tables. Sidereal time of Greenwich, mean noon, is given for reducing sidereal time to mean time, and conversely. The formulas for azimuth, time of elongation and azimuth of Polaris, at any hour angle, as well as the formulas for equal altitudes of the sun, are previously given. Mean time is the interval after mean noon. Convert this interval into the equivalent sidereal interval and add to the sidereal time of noon. Sidereal time, noon, is equal to the right ascension of the mean sun at that instant. 9.8565 s. multiplied by the longitude of the observer and applied to Greenwich sidereal time of mean noon (see Table 2), plus when west, will give the local sidereal time of mean noon, or right ascension of mean sun of observer.

* This addition to the paper by N. B. Sweitzer, Assoc. M. Am. Soc. C. E., was not received with the original manuscript, but sent in later. It is printed here for the benefit of those who wish to discuss the paper.

TABLE 2.—*Alpha Ursæ Minoris* FOR THE 90TH MERIDIAN WEST FROM GREENWICH. ASTRONOMICAL TIME. LATITUDE 45°. APPARENT δ AND α WITH GREENWICH SIDEREAL TIME OF MEAN NOON, FOR THE YEAR 1912.

Date.	Right ascension.	Declination.	Upper culmination.	Diff. for 1 day, U. C.	W. elongation.	Gr. sid. time of mean noon. Diff. 1 hour + 9.8565 s.
	h. m.		h. m. s.	m.	h. m.	h. m. s.
	1 27	88° 50′				
1912	s.					
Jan. 1	38.5	30.8″	6 46 25	3.95	12 40.8	18 39 07.5
15	24.0	22.1″	5 51 08	3.95	11 45.5	19 34 19.4
Feb. 1	06.0	32.0″	4 43 59	3.95	10 38.3	20 41 20.8
	h. m.					
	1 26					
	s.					
15	52.2	30.5″	3 48 43	3.95	9 43.1	21 36 32.6
Mar. 1	39.6	27.7″	2 49 32	3.94	8 43.9	22 35 40.9
15	31.2	24.1″	1 54 21	3.94	7 48.7	23 30 52.7
Apl. 1	25.5	19.1″	47 25	3.94	6 41.8	37 54.1
15	25.5	14.5″	23 48 26	3.93	5 46.7	1 33 05.9
May 1	30.9	9.9″	22 45 36	3.93	4 43.8	2 36 10.7
					E. elongation.	
15	38.9	6.5″	21 50 42	3.92	15 56.3	3 31 22.5
June 1	52.9	3.5″	20 44 05	3.92	14 49.7	4 38 24.0
	h. m.					
	1 27					
	s.					
15	06.4	2.0″	19 49 16	3.91	13 54.9	5 33 35.8
July 1	23.0	1.7″	18 46 38	3.91	12 52.2	6 36 40.8
15	38.2	2.5″	17 51 50	3.92	11 57.5	7 31 52.6
Aug. 1	55.9	4.7″	16 45 17	3.92	10 50.9	8 38 54.1
	h. m.					
	1 28					
	s.					
15	09.6	7.7″	15 50 28	3.92	9 56.1	9 34 05.9
Sep. 1	24.2	12.3″	14 43 53	3.92	8 49.5	10 41 07.3
15	33.8	16.9″	13 49 00	3.93	7 54.6	11 36 19.0
Oct. 1	41.7	22.7″	12 46 13	3.93	6 51.8	12 39 23.9
15	45.2	28.2″	11 51 14	3.93	5 56.8	13 34 35.7
Nov. 1	44.8	34.9″	10 44 23	3.93	4 50.0	14 41 37.1
					W. elongation.	
15	40.9	40.0″	9 49 16	3.94	15 43.6	15 36 48.9
Dec. 1	32.1	45.2″	8 46 13	3.94	14 40.6	16 39 53.8
15	21.6	48.9″	7 51 00	3.95	13 45.4	17 35 05.6
1913						
Jan. 1	05.8	51.9″	6 43 53	3.95	12 38.3	18 42 07.1

The civil day begins 12 hours before the astronomical day ; and the first period of the civil day answers to the last part of the preceding astronomical day—thus, May 15th, 15h. 56.3m. astronomical time is the same as May 16th, 3h. 56.3m. A. M., civil time.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE HALLIGAN DAM: A REINFORCED MASONRY STRUCTURE.

Discussion.*

By Messrs. L. J. Mensch and Edward L. Sayers.

L. J. Mensch, M. Am. Soc. C. E. (by letter).—Mr. Houston is to be commended for bringing up for discussion the very interesting subject of arched dams, and for having at last tried to leave the rut and take advantage of the site to adopt an arched structure. Unfortunately, the span was too large, and it is doubtful whether a great portion of the dam acts as an arched dam at all. Mr. Mensch.

Many years ago the writer investigated carefully the action of arched dams, and found that it requires the skill of a high-class mathematician to formulate the laws of the combined action of the arch and gravity principle into a workable shape. The safety of a design, however, can be checked by comparatively simple means. If a tube is subjected to an exterior pressure, the diminution of the radius due to a uniform load, p, per square inch,

$$\Delta = \frac{p\,r^2}{E\,d} \quad \text{(1)}$$

where r is the radius, and d is the thickness of the shell, both in inches; and, inversely, $p = \frac{E\,d\,\Delta}{r^2}$.

This formula, however, cannot be applied to every section of an arched dam, because the deflection of the arch is greatest in the center and zero at the abutments. Although there is no deflection at the abutments, still, as in any ordinary arch, it is known that the compression there is greater than in the center.

* Continued from January, 1912, *Proceedings*.

Mr. Mensch.

On account of this unequal shortening of the arch, great stresses appear at the center and twice as great stresses at the abutments, and, on account of the relatively great thickness of the arch, these stresses may be even higher than those due to compression alone.

The deformation in the center of an ideal arched dam, for the various layers below the water line, may be found by Equation 1. For a structure of the dimensions of the Halligan Dam, the full line in Fig. 5 shows the ideal deformation. The same structure as a gravity

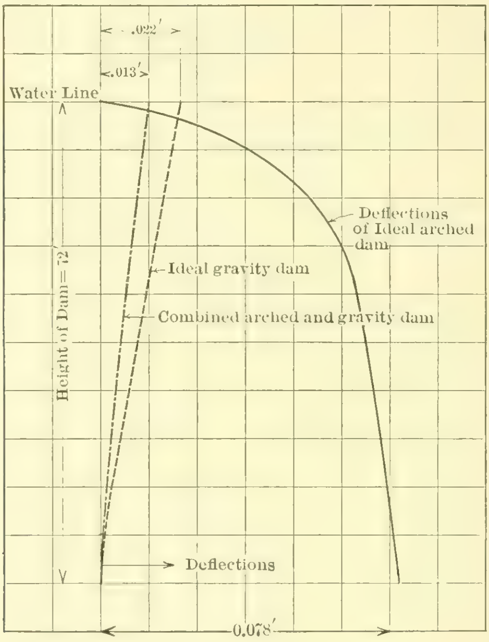


Fig. 5.

dam would deflect as shown by the dashed line in Fig. 5, if the whole water pressure were acting to deform the dam as a cantilever; and, as can be seen, this deflection is very much smaller than the deformation which would be obtained if the entire water pressure acted on the dam on the arch principle. Therefore, in a combined arch and gravity structure of the dimensions of the Halligan Dam, only a very small part of the stresses can be taken up by the arched principle.

It can be stated that the bending moment at the base, which is due to the gravity action in the combined arched and gravity dam, depends on the value of $\frac{h^4}{d^2\, r^2}$, and can be obtained by the general formula, $M = \frac{p\, h^3}{n}$, in which h is the height of the dam.

For example: Mr. Mensch.

$\frac{h^4}{r^2\,d^2} = 0$	0.31	0.384	0.504	1.358	9.166
$n = 6$	6.71	6.88	7.15	8.75	16.

This is only for the center section of the dam, and requires a new calculation for every other section.

There is no question that an arched structure, if it is properly designed and if the site affords proper abutments, is safer than a gravity dam alone, because water pressure entering in the joints or under the base only facilitates the arch action, even if it destroys the gravity action.

Edward L. Sayers, Assoc. M. Am. Soc. C. E. (by letter).—The striking feature of this paper is the extreme simplicity of the "analysis of stresses" which forms the basis of the design. It is not usual to base the design of so important a structure as a dam of this height on such meager calculations, but it must be assumed that the author has put this paper forward in good faith, and that the dam was actually designed with this analysis as a base. Mr. Sayers.

The investigation of the distribution of the stresses in an engineering structure is frequently the greatest difficulty confronting the designer. Mr. Houston, in his treatment of this problem, has disposed of such doubtful points by assumption. Seven assumptions are given as the basis of the analysis, and the method of the analysis itself constitutes still another, and, in fact, the main assumption. In general, all assumptions, when made the basis of a design, need defense, but this seems to have been entirely overlooked in the paper. If the design of any structure is based on an analysis involving assumptions, it should be shown, either that they approximate the truth and what the limits of error are, or, if they do not closely approximate the truth, it should be shown that the error involved is on the side of safety; that is, that the computed stresses are greater than can actually exist.

The wording of the paper ("The following analysis of the stresses in the dam * * *," etc., "Fig. 3 is a diagram of the stresses acting on the dam," "The factor of safety is about 6," and "Table 2, Summary of Stresses," etc.) would imply that the assumptions are supposed to represent at least approximate truths, and yet this can hardly be the case, because they are so evidently impossible and inconsistent that they must have been thought to represent conditions on the safe side rather than approximations to the truth.

In his computations, the author assumes a fixed position of the neutral axis, the neutral axis being assumed at a distance of 0.4 of the effective thickness of the dam from the down-stream face (there is a slight inconsistency in this when taken with the assumption that the center of gravity of the compressive stress is at a point distant

Mr. Sayers.

0.15 of the effective thickness of the dam from the down-stream face), and the intensity of stress in the steel being assumed as constant at 12 000 lb. per sq. in. at any elevation in the dam. These assumptions can only be made together with the further inconsistent assumption that the modulus of elasticity for the concrete varies at different depths below the water surface. The following calculations show this variation of the modulus of elasticity and the unusually low values resulting. Referring to Fig. 3 (retaining the author's notation and assumptions), and further noting that his stress diagram assumes uniformly varying stress, we have the following relation:

$$\frac{\dfrac{12\,000}{E_s}}{E_c} : 0.6\ (j - 0.5) :: c : 0.4\ (j - 0.5)$$

or, $$E_c = \frac{c \times 0.6 \times E_s}{0.4 \times 12\,000} = E_s \frac{c}{8\,000}$$

in which E_c = modulus of elasticity of concrete,

and E_s = modulus of elasticity of steel, taken as 30 000 000 lb. per sq. in.

TABLE 5.

Elevation.	c, in tons per square foot, taken from Table 2.	c, in pounds per square inch.	E_c, in pounds per square inch.
40	8.0	111	417 000
30	9.7	135	505 000
20	12.3	171	641 000
10	13.5	188	703 000
0	15.7	218	818 000

The error here involved may possibly be on the side of safety; and, while it may be true that the modulus of elasticity of the concrete is not constant, may it not vary in some other manner than that selected by the author? At any rate, the assumptions made cannot result in computed stresses which are either consistent or close approximations to the probable actual, and it would seem to be unwarranted, because the assumption of a constant modulus of elasticity, instead of a constant steel stress or a constant relative position of the neutral axis, would have complicated the mathematics but slightly.

It may be noted that the author states his fifth assumption as: "That the safe load (tension) on the reinforcement is 12 000 lb. per sq. in." In that statement he does not assume that the stress in the steel of the dam is actually 12 000 lb. per sq. in., but that figure is used in all his computations of stresses, which would preclude the theory that the computed stresses are approximations to the actual, while the inconsistencies throw doubt on their safety.

The main assumption on which the analysis is based is as follows: That part of the water pressure which cannot be carried safely by the

dam considered as a beam will be carried by the dam considered as an arch. This involves a further assumption that the dam considered as a cantilever beam will have a maximum deflection at the top and a minimum deflection at the bottom, while the dam considered as an arch (referring to the intensities of thrust in Table 2) will have a minimum deflection at the top and a maximum at the bottom. For instance, in Table 2 the computed thrust in the arch is 4.4 tons per sq. ft. at Elevation 40, while at Elevation 0 it is 10.5 tons per sq. ft.; this means that the arch must deflect at Elevation 0, say, twice as much as at Elevation 40, while, on the other hand, according to the beam calculations, there is a maximum deflection at the top, decreasing to zero at Elevation 0. That these two sets of stresses, with their respective deflections, should exist simultaneously is obviously impossible. Furthermore, it is known that the dam cannot deflect at its base, and it follows (as stress must always be attended by deformation) that no such intensities of thrust from arch action as are shown in Table 2 can exist in the dam close to the base, and, therefore, the load there assumed to be carried by the arch must be carried by the beam. Mr. Sayers.

It is possible that the stresses in the dam will be distributed and adjusted between arch and beam action so that the dam will be safe, but the analysis of the paper fails to show this, and, therefore, in spite of the author's statement that his design is one in which the stresses can be demonstrated to be safe, it must be concluded that his analysis gives stresses which are neither approximate nor necessarily on the side of safety.

Computations of the approximate actual stresses, based on the relative elasticity of the dam acting as an arch and as a cantilever beam, can be made, and it is believed that they should always be a part of the process of design of a dam of this character. It may be pointed out here that it is not enough to show that the dam is safe when its gravity action is completely ignored, for the fixing of the base of the dam may throw a greater load on the arch in the upper portion than is received directly from the water pressure on it.

The author's computations assume a stress of 12 000 lb. per sq. in. in the steel. When reinforcing steel is stressed to this extent, the surrounding concrete must crack. If the concrete is uniform in quality, these cracks may be distributed, and will be small, yet large enough to admit water under the full head. If, however, there exist planes of relative weakness, such as are likely to occur at the joinings of new work to old, or even at places where one day's work ends and another begins, these cracks will be localized and may extend to a greater depth into the dam, and even to the neutral axis, and will admit water.

The author, in Fig. 3 and in his computations, has practically assumed a crack, but neglected the force of the water pressure acting therein. The effect of this pressure would be to extend the crack; but,

Mr. Sayers. supposing it to extend to the author's assumed position of the neutral axis, and remembering that he assumes this position independently of the steel stress, the tension in the steel would be

$$\frac{w\,h \left\{ 0.5 + 0.6\,(j - 0.5) \right\} \dfrac{0.55\,j - 0.025}{m}}{\text{Area of steel.}} + 12\,000$$

or, at	Elevation	40	it	would	be	50 000	lb.	per	sq. in.
"	"	30	"	"	"	75 000	"	"	" "
"	"	20	"	"	"	46 000	"	"	" "
"	"	10	"	"	"	61 000	"	"	" "
"	"	0	"	"	"	74 000	"	"	" "

These figures are not introduced as a prediction of the actual stresses in the dam, but to show to what the author's figures would logically lead, and to suggest a possible serious feature which should have been investigated.

It may be argued that, considered only as an arch, the dam may be safe, having only an average stress of about 27 tons per sq. ft., but this stress is computed under the most favorable assumption as to its distribution. It is certain that the line of thrust will not coincide with the axis of the dam, and, therefore, will not produce a uniform distribution of stress across the arch. This is especially true because the combined shortening from shrinkage, low temperature, and direct stress will have the effect of throwing the line of thrust toward the down-stream face at the abutments, and toward the up-stream face at the middle.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROVISION FOR UPLIFT AND ICE PRESSURE IN DESIGNING MASONRY DAMS.

Discussion.*

By Messrs. Edward Wegmann, Charles E. Gregory, Orrin L. Brodie, H. F. Dunham, C. Elmore Smith, and J. C. Meem.

Edward Wegmann, M. Am. Soc. C. E.—The questions connected with the design of masonry dams, presented for discussion by Mr. Harrison, are of great importance. In this paper the author has indicated the conclusions at which one should arrive with reference to upward water pressure under the base of a dam in designing the profile, namely, that it would depend on the rock on which the dam was to be founded. In some cases there might be considerable upward pressure, while in others little, if any, allowance should be made for such a force. Mr. Wegmann.

It might be of interest to examine briefly the evolution of the theory of designing masonry dams. Prior to 1853 such dams were built without any rational consideration of the forces which they had to resist. Some of these structures would be stronger if they could be turned about so as to make their up-stream faces their down-stream sides.

The French engineer, De Sazilly, in his paper on "A Profile-Type of Equal Resistance for Reservoir Walls,"† explained, for the first time, the principles on which the design of a masonry dam should be based. His theory was that, in order to be safe, the structure should have a sufficient factor of safety against overturning and sliding, and that the maximum pressure to which the masonry and foundation were to be exposed should not exceed a safe limit. As far as the last

* Continued from January, 1912, *Proceedings*.

† *Annales des Ponts et Chaussées*, 1853, Vol. II, pp. 191–222.

Mr. Wegmann. mentioned element of strength is concerned, De Sazilly's ideal type of dam was one in which the maximum pressures in the masonry, at different levels, were exactly equal to the highest allowable amount.

Delocre, Bouvier, Pelletreau, Lévy, and some other French engineers, have written papers, proposing profiles differing somewhat from De Sazilly's type. Professor Rankine added to the requirements established by the French engineers the important condition that the lines of pressure, for reservoir full or empty, should be kept within the center-third of the profile, in order to avoid tension in the masonry; and he also pointed out that the assumed limit of vertical pressure should be lower at the down-stream face than at the up-stream face. The profile designed by Rankine, which was adopted for the Toolsay Dam, near Bombay, 79 ft. high, was bounded by logarithmic curves.

As far as the speaker knows, none of the engineers mentioned took into account an upward pressure under the base of the dam, or ice pressure, and yet, a great many dams have been built according to their types and none has failed, with the exception of one in France, built on a bad foundation, and another in Africa, constructed in a very defective manner.

In 1884 the engineers of the Aqueduct Commission of the City of New York had to design a masonry dam, from 275 to 300 ft. high, which was to be built across the Croton River, near its mouth, to form a large storage reservoir for the water supply of that city. The site originally selected for the proposed dam was at the Old Quaker Bridge, about 4 miles above the mouth of the river, and, because of this location, it was called the Quaker Bridge Dam. The structure was eventually built, in 1892 to 1907, $1\frac{1}{4}$ miles farther up stream, and was named the New Croton Dam, in contradistinction to the Old Croton Dam, 3 miles farther up stream, built in 1837 to 1842.

The necessary studies and investigations were made under the direction of the late Alphonse Fteley, Past-President, Am. Soc. C. E., Deputy Chief Engineer, and later Chief Engineer, of the Aqueduct Commission, and it was the speaker's privilege to be Mr. Fteley's principal assistant in this matter.

The highest reservoir wall in existence in 1884 was the famous Furens Dam, near Saint Etienne, France, which had a maximum height of about 184 ft. above the foundation. In America there was at that time only one masonry dam, not considering low structures, namely, the Boyd's Corners Dam, built in 1866 to 1873, across the West Branch of the Croton, and having a maximum height of 78 ft. above the foundation.

The formulas for determining the proper profile of a masonry dam, which had been published up to that time (namely, those of De Sazilly, Delocre, Rankine, Pelletreau, De Bauve, etc.), were very complicated and unsatisfactory. They required that the maximum pressures in

Mr. Wegmann.

the dam, at different levels, should be kept at a fixed limit of safety, which was taken by these different engineers at from 6 to 10 tons per sq. ft. If the design of the proposed dam across the Croton River had been based on such data, its down-stream face would have become almost horizontal at a depth of 300 ft. The only practical solution of the problem was to assume a higher limit for the permissible pressure in the masonry and on the foundation, and this was fixed by the engineers of the Aqueduct Commission at 32 000 lb. per sq. ft., or about twice as much as had been considered safe by the French engineers up to that time. What confirmed the designers of the New Croton Dam in the reasonableness of their assumption of maximum pressure was, not only experiments on the crushing strength of masonry, but the fact that the Almanza Dam, built in Spain prior to 1586, the oldest masonry dam in existence, was sustaining safely a pressure of about 14 tons per sq. ft.

The possibility of an upward pressure under the base of the dam was considered carefully by the engineers of the Aqueduct Commission and by a Board of Experts consisting of three prominent engineers, Messrs. J. P. Davis, J. J. R. Croes, and W. F. Shunk, and such a force was left out of consideration, in this case, on the ground that with the depth to which the foundation was to be excavated and the care contemplated in closing all fissures and seams in the rock, an upward pressure, if it occurred at all, would in all probability extend over only a very small part of the base.

The Board of Experts advised that the dam be curved in plan, and that it be designed to resist, in addition to the water pressure, an ice thrust of 43 000 lb. per lin. ft. at the highest ice line. The plan submitted by this Board, however, was not adopted, and the dam was built straight in plan, no attention being given to upward pressure or ice thrust.

Mr. Fteley, who had had large experience in the construction of dams, followed the same method in designing two other masonry reservoir walls in the Croton water-shed, namely, the Sodom Dam, 98 ft. high, built in 1888 to 1893, and the Titicus Dam, 135 ft. high, built in 1890 to 1895.

The three dams just mentioned are standing successfully, and do not show the slightest indication of weakness. Thus far, the New Croton Dam is the greatest work of its kind. The Shoshone Dam, in Wyoming, surpasses it in height by about 25 ft., and the Assuan Dam, in Egypt, contains a greater quantity of masonry, owing to its great length; but the former is built across a narrow cañon, and the latter has a maximum height of only about 112 ft. The Olive Bridge Dam, now being built in connection with the Ashokan Reservoir, in Ulster County, for the City of New York, has a maximum height of only 252 ft.

Mr. Wegmann.

In 1895 John D. Van Buren, M. Am. Soc. C. E., in a paper entitled "Notes on High Masonry Dams,"* advocated that a masonry dam be made strong enough to resist a pressure under its base equal to the full hydrostatic head in the reservoir, and that in northern latitudes the dam should also be able to withstand an ice pressure of about 40 000 lb. per lin. ft. at its highest ice line. With these conditions, he designed the profile shown in Fig. 3,† the width of the base being 352 ft. and the height 250 ft. If these principles had been followed in designing the New Croton Dam, having a maximum height of 297 ft. above the foundation, its base would have been more than 400 ft. wide, instead of 206 ft., as actually built.

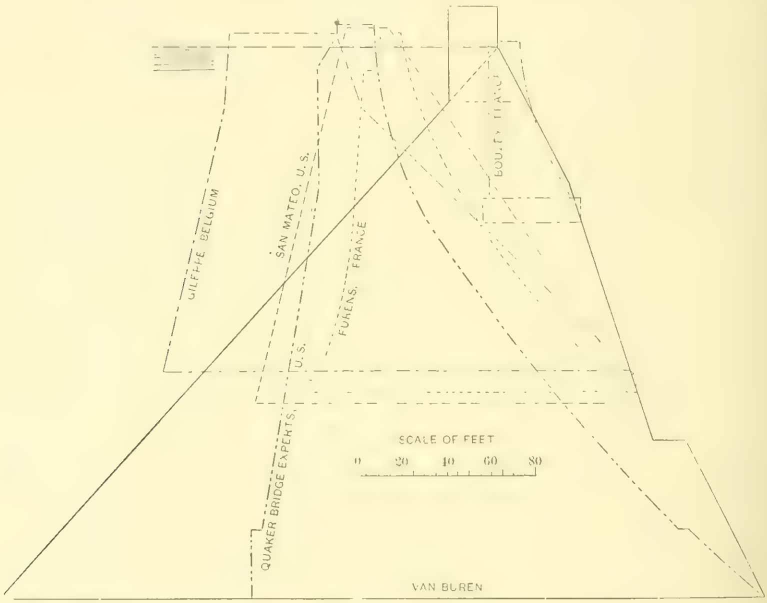


FIG. 3.

According to a letter by G. M. Braune, Assoc. M. Am. Soc. C. E.,‡ the Marklissa Dam, in Prussia, completed in 1904, was designed to resist a pressure under its base equal to the full hydrostatic pressure in the reservoir, "in order to allay the fears of the citizens living below the dam." In this case the width of the base was about 87% of the height (namely, width of base 37.7 m. for a height of 43 m.). Masonry dams might be built on foundations so porous as to justify the extreme assumption on which the design of the Marklissa Dam was based, but such cases are likely to be extremely rare; and, to adopt

* *Transactions*, Am. Soc. C. E., Vol. XXXIV, p. 493.

† Reproduced from Mr. Van Buren's paper.

‡ *Engineering News*, Nov. 30th. 1911, p. 661.

such a design for an ordinary foundation, would be like calculating a bridge for a factor of safety of 10, when experience had shown that 6 was ample. Mr. Wegmann.

The Wachusett Dam, built in Massachusetts in 1900 to 1906, was the first American dam in the design of which an upward pressure under the base was taken into account. In this case there was a town of 13 000 inhabitants about half a mile below the site, and failure would have caused a great disaster. Under these circumstances, the engineers adopted a very strong profile, calculated to resist an upward pressure under the base equal to two-thirds of the pressure of the water at the up-stream face and diminishing uniformly to zero at the down-stream toe, and, also, an ice pressure of 47 000 lb. per lin. ft. of dam at the highest ice line.

In the Cross River and Croton Falls Dams, built recently in the Croton water-shed, the designs were based on similar conditions, an upward pressure under the base being calculated in the same manner as for the Wachusett Dam, but the ice pressure per linear foot was taken at only 24 000 lb. for the Cross River Dam, and at 30 000 lb. for the Croton Falls Dam. These structures are near the New Croton Reservoir, no habitations being directly below them, and under these circumstances it is a debatable question whether the profiles should have been made as strong as they were.

There are three cases of failures of masonry dams on record in which upward pressure under the base of the structure, for which no allowance had been made in the design, doubtless played a large part. Some particulars regarding these dams are given in Table 1. They were all built on poor foundations.

TABLE 1.—Masonry Dams in Which the Failure was Largely Due to Upward Pressure.

Name of dam.	Location.	Maximum height.	Built.	Failed.
Bouzey	France	72 ft.	1878–1881	April 27th, 1895.
Austin	Texas	68 "	1891–1892	April 7th, 1900.
Austin	Pennsylvania	50 "	1909–1910	Sept. 30th, 1911.

The Bouzey Dam was founded on red sandstone, which was fissured and quite permeable. The foundation for the dam itself was only excavated to fairly good bottom, and not to solid rock. A cut-off wall, 2 m. thick, was built at the up-stream face, from solid rock to the river bed. The first time the reservoir was filled, a portion of the dam, about 440 ft. long, was shoved forward so as to form a curve, convex down stream, having a versed sine of 1.1 ft. The dam was reinforced by building, on its down-stream side, an abutment which was connected with the dam by an inclined wall toothed into the dam. This, however,

Mr. Wegmann. proved to be insufficient, and about 590 ft. of the dam was overturned as soon as the reservoir was filled again.

The dam across the Colorado River at Austin, Tex., was built on a foundation which was very poor in places, part of it being on a fault, 75 ft. wide, filled with adobe with an occasional streak of red clay. The foundation trench was not excavated deep enough, and the protection against erosion on the down-stream side was insufficient.

The failure of the dam at Austin, Pa., is so recent that it does not need much description here. The dam was founded on sandstone, underlaid by shale having fissures filled with clay, sand, and gravel.

In each of these three cases there was, doubtless, considerable upward pressure under the base, and each profile should have been designed to give the dam sufficient strength to resist such a force.

From the foregoing facts, the speaker draws the conclusion that uplift under a dam may vary from nothing to a considerable force. How much upward pressure should be assumed in any given case is purely a matter of judgment, and in each case it is advisable for the engineer to consult some experienced geologist.

Some water will find its way through the best built masonry dam and will appear as damp spots on its down-stream face. The question has been raised as to whether such water might not exert some upward pressure in the masonry. Unless some provision for expansion and contraction is made, cracks are sure to occur in the masonry. If these cracks are nearly vertical, little or no upward pressure will be caused by water from the reservoir filling them; but if the expansion cracks are about horizontal, upward pressure will, doubtless, occur in the masonry, its magnitude depending on the depth to which the cracks extend into the wall.

When uplift under the base of a dam is considered in designing the profile, provision is usually made for it at any level above the base, as the same profile is generally used for the highest parts of the dam and for the low parts at the two ends. For this reason the profile would be designed so that, when the base was taken at any level below the top of the dam, the masonry above the base would have ample strength to resist the thrust of the water on its up-stream face and, also, the assumed upward pressure under its base.

The question as to how much should be allowed in northern latitudes for ice pressure against a masonry dam is difficult to answer with the information now available. Ice, when confined, as between two bridge piers, doubtless exerts great pressure in expanding, but when this ice is in a reservoir having sloping banks, the dam being usually in a narrow gorge, it is doubtful whether it would exert much pressure against the dam. Ice forms every winter against weak mill-dams, and yet we do not hear that they are ruptured by it. It would be interesting if experiments were made to measure the expansive force of ice,

but this is difficult to accomplish on a scale sufficiently large to be of value. One way to make such a test would be to let ice form directly against flash-boards, first determining their resistance to overturning and shearing, and then noticing whether they were forced out. Mr. Wegmann.

It is certain that, if the great uplift and ice pressure which some engineers recommend had been realized, many masonry dams, now standing successfully, would have been ruptured long ago.

The speaker has tested by calculation the strength of some American and foreign dams to withstand a full upward pressure under their bases, and an ice pressure of 25 tons per lin. ft., an assumption which some engineers think should be made in designing, and has found the lines of pressure, reservoir full, to fall for a great part outside of the profile. In such a case a dam would be overturned unless this were prevented by the tensile strength of the masonry. The speaker is satisfied that such a condition does not exist in the dams to which he refers. As far as the speaker knows, only one case is on record in which the expansion of ice was probably the primary cause of the failure of a dam; this was the partial failure of such a structure at Minneapolis, Minn.* In this case, however, there were special conditions.

In conclusion, it may be stated that, if ample security against failure were all that the engineer had to seek in designing a dam, his task would be very easy. He might follow the simple rule of making the width of the dam, at any level, equal to one and one-half times the height, and feel sure that nothing short of an earthquake would cause rupture. There remains, however, the consideration of cost, and the best engineer is he who obtains the required security and architectural appearance of the dam, at the least expense. Engineers designing works to be built for great cities are somewhat relieved from the necessity of counting the costs of the projected work, as they may feel quite confident that whatever plan they may recommend will be carried out. It is very different, however, when private capital furnishes the means for building such works. The engineer who combines, with his theoretical knowledge, sound judgment and courage to follow his convictions, is the ideal type which all should strive to follow.

Charles E. Gregory, Assoc. M. Am. Soc. C. E.—The influence of the upward pressure of water and of ice thrust on the stability of masonry dams, together with the actual internal distribution of stress in very large masses of masonry, are probably the most indefinite factors in the design of such structures. Mr. Gregory.

The speaker, as Designing Engineer, under the direction of J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer, and Alfred D.

* *Engineering News*, May 11th, 1899; and *Engineering Record*, May 13th, 1899.

Mr. Gregory. Flinn, M. Am. Soc. C. E., Department Engineer, of the New York Board of Water Supply, has designed two high masonry dams. The first, Olive Bridge Dam, helps to form Ashokan Reservoir, about 13 miles west of Kingston, N. Y; the second, Kensico Dam, forms Kensico Reservoir, at Valhalla, N. Y. Fig. 4 is a cross-section of Olive Bridge Dam, and on Plate XI there is a cross-section of Kensico Dam, as well as brief statements of the assumptions made in its design, pressure lines, diagrams of maximum compressive stresses, vertical and horizontal shearing stresses, etc. On each illustration

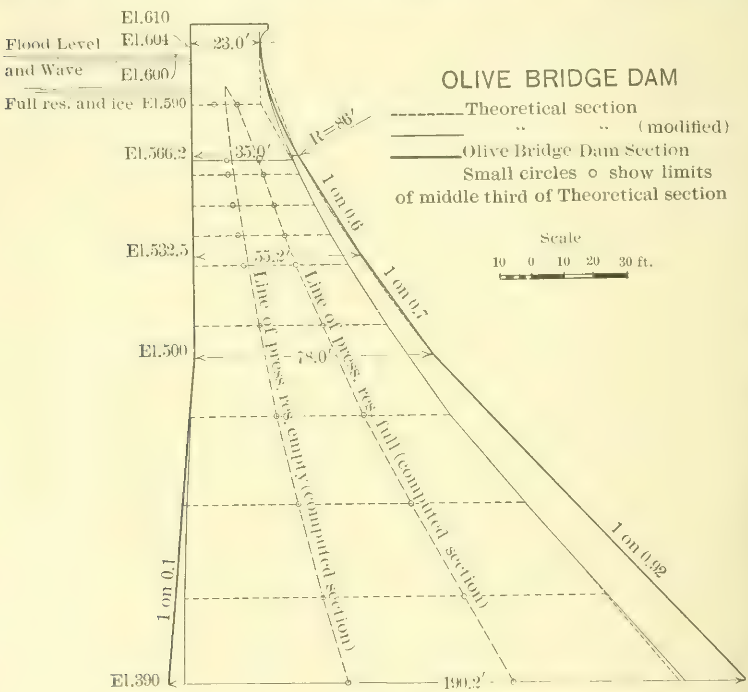


FIG. 4.

there is a "theoretical section" obtained from the assumptions stated on Plate XI and the further condition that there should be no stress at the up-stream edge. These sections were worked out by a direct analytical method, developed under the speaker's direction, by O. L. Brodie, Assoc. M. Am. Soc. C. E., for the Olive Bridge Dam, and described by him in his discussion of this paper.

The bulge in the theoretical section just below the flow line indicates the influence of the ice pressure. The ice thrust has a greater influence on the thickness of the dam than the flood-water level, down to about 110 ft. below the flow line in the Olive Bridge Dam, at which point the 10-ft. flood level begins to require a wider base; and

in Kensico Dam, with a flood level of 5 ft., the change is about 210 ft. below, indicating that, for dams of moderate height, ice pressure has a great influence. Mr. Gregory.

Kensico Dam at its greatest height is expected to extend more than 130 ft. below the surface of the ground. In designing this section, the effect of the earth and water pressure against both sides of the dam, and their influence on the uplift under the bottom, were taken into account, as indicated on Plate XI. The effect of the earth pressures on the down-stream slope is to increase the unit compressive stress in the masonry, but to decrease the overturning moment.

The weight of the masonry was corrected for the galleries and wells, and was found to be very nearly two and one-third times the weight of water, and this value was adopted. For these dams, both analytical and graphical methods of determining stresses were used for the adopted sections, and these were made greater than the "theoretical" sections for the following reasons:

(1) Both dams are just above very populous districts, and their failure would be such a calamity that a liberal factor of safety was thought to be imperative;
(2) The face of the dam, being of a different kind of masonry than the interior, may in time separate from the main body, and become practically useless;
(3) Interior, vertical, longitudinal cracks may weaken the dam by separating it into two or three parts, which, to some extent, will act separately, thus destroying the vertical shearing strength of the section.

Both these dams are built on stratified rock, and each is to have a cut-off of considerable depth along its up-stream face. The stratification planes at the Olive Bridge Dam are nearly horizontal; at Kensico, they are inclined about 45° to the axis of the dam. The ordinary masonry dam built on a stratified rock is most likely to fail by sliding, if the down-stream toe does not abut against solid rock. In addition to the friction between planes due to the weight of the dam, which is ample, sliding along a stratification plane is prevented in these dams by the depth to which the masonry is built into the rock, the toe abutting horizontally against an approximately vertical face of rock.

As Mr. Harrison states, upward pressure may be due to water getting into the foundation or into the dam itself. The foundation conditions at the Olive Bridge Dam are quite similar to his Case 2, and those for the Kensico Dam are in effect like Case 3. The cut-off trench in each case undoubtedly reduces the leakage, but might not cut down the pressure materially, as experience has shown it to be very difficult to build a concrete wall of the lengths required without shrinkage and temperature cracks.

Mr. Gregory.

The part of the base over which the pressure is active cannot be the entire area, unless the dam is actually floating. The total pressure on the parts of the joint in contact must equal the difference between the weight of the dam and the uplift of the water, and must be within the crushing strength of the parts in direct contact, or say, not more than 500 lb. per sq. in. The assumption that only one-third of the rock faces are in direct contact gives pressures as great as probably occur, and leads to the conservative assumption of upward water pressure over two-thirds of the base, and varying according to the resistance losses in passing through the rock or masonry. Where upward pressure must be provided for at the base, very little, if any, economy is possible in designing the portions above without allowing for it.

In all but the portions below the creek bed, water pressures in the masonry are controlled by vertical drainage wells about 10 ft. from the up-stream face and 12 ft. apart.

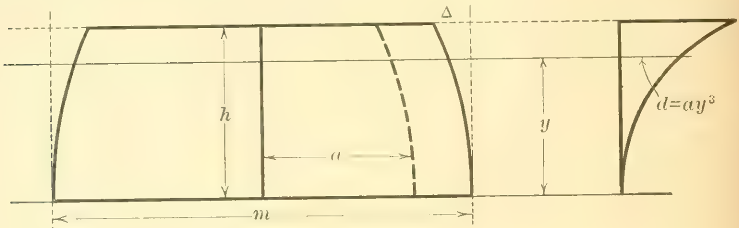
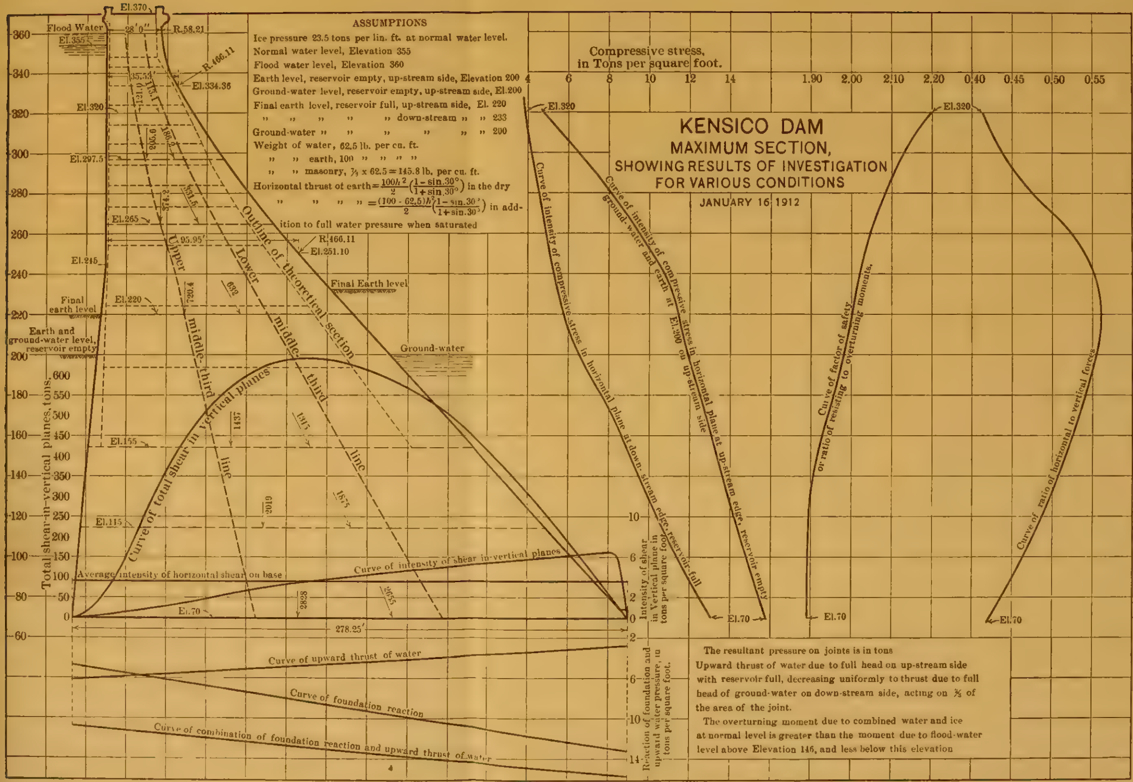


Fig. 5.

Water may enter the masonry through the small pores in the mortar, where no cracks or joints exist; but the uplift which it exerts cannot be applied over a greater part of the joint than is indicated by the fraction obtained from dividing the percentage, by weight, of water which the masonry will absorb by the percentage of voids in the mass before setting. Water, however, is more likely to enter the body of a cyclopean masonry or concrete dam, so as to cause a material uplift, through defective construction joints, as in the dam at Austin, Pa., or through temperature cracks. Large bodies of Portland cement concrete which have been deposited rapidly during a summer season maintain a temperature of more than 100° Fahr., for a long time, due to chemical action while the cement is setting. In winter the low temperature of the atmosphere reduces the temperature of the outside skin to a point 60° and possibly 100° below that which is maintained by chemical action several feet from the surface, and the consequent contraction of the outside causes cracks which seek to follow weak lines in any direction in which they may occur.

Such cracks will occur in first-class masonry as well as in that of inferior quality, and will probably be larger and farther apart the


KENSICO DAM
MAXIMUM SECTION,
SHOWING RESULTS OF INVESTIGATION
FOR VARIOUS CONDITIONS
JANUARY 16 1912
ASSUMPTIONS
Ice pressure 23.5 tons per lin. ft. at normal water level.
Normal water level, Elevation 355
Flood water level, Elevation 360
Earth level, reservoir empty, up-stream side, Elevation 200
Ground-water level, reservoir empty, up-stream side, El. 200
Final earth level, reservoir full, up-stream side, El. 220
" " " " " down-stream " " 233
Ground-water " " " " " " 200
Weight of water, 62.5 lb. per cu. ft.
" " earth, 100 " " " "
" " masonry, ⅓ x 62.5 = 145.8 lb. per cu. ft.
Horizontal thrust of earth = $\frac{100h^2}{2}\left(\frac{1-\sin 30^\circ}{1+\sin 30^\circ}\right)$ in the dry
" " " " = $\frac{(100-62.5)h^2}{2}\left(\frac{1-\sin 30^\circ}{1+\sin 30^\circ}\right)$ in addition to full water pressure when saturated
Compressive stress, in Tons per square foot.
4 6 8 10 12 14 1.90 2.00 2.10 2.20 0.40 0.45 0.50 0.55
El.370
Flood Water
El.355
28' 0"
R.58.21
R.466.11
El.334.36
El.320
El.297.5
El.265
95.95'
R.466.11
El.251.10
El.245
El.220
Final earth level
Earth and ground-water level, reservoir empty
El.155
El.115
El.70
278.25'
Outline of theoretical section
Upper middle third line
Lower middle third line
Final Earth level
Ground-water
Curve of total shear in vertical planes
Total shear in vertical planes, tons.
Average intensity of horizontal shear on base
Curve of intensity of shear in vertical planes
Intensity of shear in Vertical plane in tons per square foot
Curve of upward thrust of water
Curve of foundation reaction
Curve of combination of foundation reaction and upward thrust of water
Reaction of foundation and upward water pressure, in tons per square foot.
Curve of intensity of compressive stress in horizontal plane at down-stream edge, reservoir full
Curve of intensity of compressive stress in horizontal plane at up-stream edge, reservoir empty
ground-water and earth at El.200 on up-stream side
Curve of factor of safety or ratio of resisting to overturning moments.
Curve of ratio of horizontal to vertical forces
The resultant pressure on joints is in tons
Upward thrust of water due to full head on up-stream side with reservoir full, decreasing uniformly to thrust due to full head of ground-water on down-stream side, acting on ⅔ of the area of the joint.
The overturning moment due to combined water and ice at normal level is greater than the moment due to flood-water level above Elevation 146, and less below this elevation

stronger the concrete. A general formula for indicating the spacing of temperature cracks, used by F. F. Moore, M. Am. Soc. C. E., may be applied here, and would be as follows: Mr. Gregory.

In Fig 5,

Let $m =$ the distance between temperature cracks;

$h =$ the height of wall, or the distance from the outside to the point where the temperature is nearly constant;

$x =$ any distance less than $\frac{m}{2}$;

$\Delta =$ the distance the outside edge would contract if unrestrained, due to temperature changes in the distance $\dfrac{\frac{m}{2} + x}{2}$;

$d =$ degrees, Fahrenheit;

$c =$ coefficient of contraction in masonry due to temperature changes;

$f =$ the strength of concrete, in pounds per square inch;

$E =$ the modulus of elasticity of masonry.

The cantilever bounded by the vertical lines, at distances x and $\frac{m}{2}$ from the center, has deflected at its end $\triangle = \dfrac{\frac{m}{2} + x}{2} c\, d$.

If d is uniform for the depth, h, and for no crack to occur at the center,

$$\triangle = c\, d \frac{\left(\frac{m}{2} + x\right)}{2} = \frac{f\, h^4}{8\, E \dfrac{\left(\frac{m}{2} - x\right)^3}{12}}$$

and f is the maximum when $x = 0$, and

$$m = 2\, h \sqrt[4]{\frac{3\, f}{c\, d\, E}}, \text{ or } f = \frac{E\, c\, d}{3} \left(\frac{m}{2\, h}\right)^4$$

Assuming that d varies with the distance from the base, y, and that $d = a\, y^3$ and the maximum $d = a\, h^3 = d'$, where a is a constant for each value assumed for the maximum d, and that $f = c\, E\, d = c\, E\, a\, y^3$, then when

$$y = h, \triangle = \frac{c\, E\, a\, h^7}{16.8\, E \dfrac{\left(\frac{m}{2}\right)^3}{12}} = \frac{c\, d' \left(\frac{m}{2}\right)}{2}, \text{ and } m = 2\, h \sqrt[4]{\frac{10\, f}{7\, c\, d'\, E}}$$

$$\text{or } f = \frac{7}{10} c\, d'\, E \left(\frac{m}{2\, h}\right)^4$$

Mr. Gregory.

During the winter of 1910-11 numerous cracks appeared in the masonry of the partly completed Olive Bridge Dam. One of these was horizontal, and many others were vertical longitudinal ones. Similar cracks, it is said, appeared in the Pathfinder Dam, under similar circumstances. Such cracking of masonry leads to a very brief discussion of its effect on the internal strength of a dam.

Vertical cracks normal to the axis of the dam are prevented by expansion joints (or, better named, contraction joints) at proper intervals. The distance between these joints is about one-half of the maximum thickness of the dam, and consequently a longitudinal crack is more apt to occur from joint to joint than a crack across the dam between joints. The seriousness of these cracks depends on their extent and width, particularly whether they extend up through the down-stream face, whether the sides are flat planes or are very irregular and toothed into each other, and on the extent to which water under pressure has access to them. The speaker will not give any results of computations based on these various assumptions, but, from a glance at the stress diagrams for Kensico Dam, it is evident that great changes in stress would result from weakening or destroying the vertical shearing strength near the midlde or down-stream part of the dam.

As Mr. Harrison has stated, the greatest pressures due to ice are caused by the expansion (under a higher temperature) of ice formed at a low temperature. The force which might be exerted by the impact of ice floes is probably very much less than that due to expansion, as there is no probability that, in an ordinary storage reservoir, ice floes could attain sufficient velocity to cause greater pressure. Such pressures would also be exerted only over small areas at a time, because there would always be projecting points which would be broken off one at a time, thus gradually bringing the floe to rest. It was assumed that clear block ice, 1 ft. thick, might form and, under the conditions described, might expand so as to exert nearly its full crushing strength of about 47 000 lb. per lin. ft. of dam. This figure was used for the Wachusett Dam, and 43 000 lb. was recommended by the Board of Experts for the Quaker Bridge Dam, while 24 000 and 30 000 lb. per lin. ft., respectively, were assumed for the recent smaller and less important dams in the Croton water-shed at Cross River and Croton Falls. It is undoubtedly a fact that many dams have been built without making allowance for ice thrust in their design; but many such dams are made strong enough to resist considerable ice thrust by assuming a super-elevation for floods and considerable top widths for roadways. It is also true that, while the conditions assumed for the large dams of the Board of Water Supply of New York are entirely possible, they actually occur very rarely, and, in many dams, probably have not yet been met. Just the proper combination of

temperature and a stationary water surface at the maximum elevation for a sufficient time may occur, but not frequently. Mr. Gregory.

ORRIN L. BRODIE, ASSOC. M. AM. SOC. C. E. The speaker was Mr. Gregory's assistant in connection with the two large dams which he mentions. So much has been said in the discussion of this paper that there seems to be little left. However, one feature, which appears to have been overlooked, relates to one of the speaker's early experiences in connection with some small retaining wall work of which he was in charge, and in which the contractor and builder endeavored to preserve the continuity of the structure from day to day. Observations during subsequent seasons showed that although the exposed surfaces or faces of these retaining walls had been left smooth, due to the finish, cracks developed later which were identified at once as being along the horizontal planes where work had been discontinued and started again. Mr. Brodie.

These walls were subject to surcharge. The drainage from the ground behind them was considerable, and there was very noticeable seepage through these cracks, therefore, it is suggested that perhaps during the building of a large structure like a masonry dam, where the work goes on from season to season, horizontal planes of cleavage may occur, and these will admit water and thereby cause uplift.

The usual method of investigating cross-sections is to run lines of resistance through them, either graphically or analytically, under various assumed conditions; but, for a change, the speaker will consider several sections, each designed for an imposed set of conditions. It will of necessity be an academic consideration, but perhaps may be of interest. Further to fix the ideas, the conditions assumed as to general height of dam and water retained are similar to those of the dam at Austin, Pa., because it is presumed that most engineers are more or less familiar with the cross-section of that structure. It is not the intention, however, to enter into any discussion of its failure, but simply to use it as a type for illustration.

Five profiles or cross-sections are presented in Fig. 6, one of which is that of the Austin Dam; the other four are designated by the letters, *A, B, C,* and *D*. The asterisk in Table 2 signifies that *B* and *C* are subject to the same conditions of loading, the consideration of *C* being only incidental.

The conditions of loading for *A* will be ice pressure, uplift, and horizontal water pressure. The assumptions, with the exception of the ice pressure, will be similar to those used by the Board of Water Supply in its studies. The speaker has reduced the ice pressure to about one-half of that used by the Board of Water Supply, because the dam is rather low, and the excessive pressure would require a much greater top than is necessary, both in thickness and super-elevation, and, besides, only illustration and comparison are desired. Sections

Mr. Brodie. *B* and *C* are designed for uplift and horizontal water pressure only. Section *D* will provide for only the horizontal water pressure.

The uplift intensity is assumed as varying uniformly from a maximum at the heel to zero at the toe, and, as stated by Mr. Gregory, the

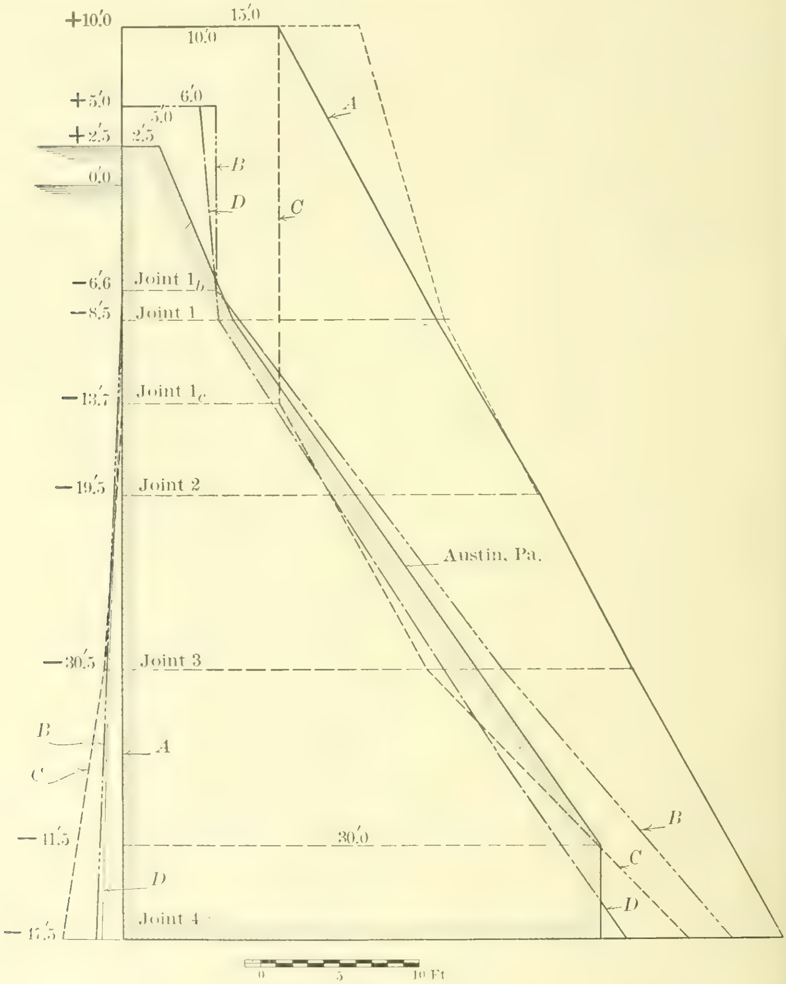


Fig. 6.

uplift is considered as acting over only a portion of the area of the joint. This is cared for by assuming only a portion of the full hydrostatic head as acting at the up-stream end of the joint considered. Two-thirds of the full up-stream head is used.

Mr. Brodie.

TABLE 2.—DIMENSIONS, CONDITIONS, ETC., FOR FIVE CROSS-SECTIONS OF DAMS.

Cross-sections	Conditions of loading.	Top width, in feet.	Super-elevation above normal reservoir surface, in feet.	Base, in feet.	Area, in square feet.	Percentage of excess of area over the area of *D*.
Austin, Pa.		2.5	2.5	30	840 ±	0 ±
A	Ice, uplift, and horizontal water thrust	10.0	10.0	41.5	1 475	76
*B**	Uplift and horizontal water thrust.	6.0	5.0	40.0	992	19
*C**	" " " " "	10.0	10.0	39.5	999	20
D	Horizontal water thrust	5.0	5.0	33.1	836	0

* *B* and *C* are subjected to the same conditions of loading.

The speaker agrees that a distinction should be drawn between the uplift conditions which may be encountered in the foundations and those higher up in the dam, and suggests that the foregoing assumptions in regard to uplift may be modified for special cases. For example, a trapezoidal (instead of a triangular) distribution of intensity due to uplift may be found advisable for a foundation. In cases where intercepting drainage wells are provided in the body of the masonry, as for the Olive Bridge and Kensico Dams, it would be reasonable to assume a triangular disposition of intensities, with the maximum at the heel as before, but running out to zero at or a little beyond the line of wells. In the former case, the total pressure would be increased but its lever arm would tend to be diminished. In the latter case, the pressure would be diminished but the lever arm increased. The effect on a cross-section design, or on a line of pressure for a given cross-section, would have to be worked out for any particular case. For such a structure as the Kensico Dam, the foregoing changes from the ordinary triangular assumption, while modifying the numerical results as to "factors" against overturning and as to resulting pressure intensities on the various joints and the foundation, did not modify the final cross-section.

In a discussion regarding ice pressures, before the Canadian Society of Civil Engineers in December, 1891, agreement seems to have been reached on two points: That thrust from ice less than 3 in. thick can be disregarded, and that the thrust can safely be taken at the crushing strength of ice.

As the compressive strength has been recorded* as ranging from 100 to 1 000 lb. per sq. in., and as there are other variable factors affecting thrust which have been pointed out in the discussions of this paper, the uncertainties of the problem are at once apparent. Addi-

* *Engineering News*, January 12th, 1893, p. 41; and also April 5th, 1894, p. 285.

Mr. Brodie. tions to the meager data now available should be made by those who have had occasion to observe ice thrust phenomena.

The value assumed in this discussion is 21 500 lb. per lin. ft. of dam. For ice about 3 in. thick, this would be equivalent to about 600 lb. per sq. in. The value used by the Board of Water Supply was 47 000 lb. per lin. ft., and is equivalent to about 650 lb. per sq. in. for ice 6 in. thick.

The condition that the lines of pressure, for reservoir full or empty, must not pass outside the middle-third limit of any joint is introduced into the equations; likewise, the condition that the maximum working pressure on any horizontal joint must never exceed certain prescribed limits. The condition limiting the inclination of the resultant is tested afterward.

The maximum working pressure condition does not need investigation here, because, for a dam of the height used in this discussion, the resulting pressure intensities are low. The line of pressure, therefore, is at the down-stream end of the middle third of each joint, reservoir filled, for each of the cross-sections, *A*, *B*, *C*, and *D*; hence, they may be considered minimum sections for their respective conditions. The fluctuation of reservoir level is taken at 2.5 ft. As ice is generally broken up during flood, the ice thrust is taken at the normal reservoir level.

The dimensions of the Austin Dam, together with the density of its masonry, 140 lb. per cu. ft., were first obtained by the speaker through the courtesy of Alfred D. Flinn, M. Am. Soc. C. E., Headquarters Department Engineer, Board of Water Supply. This weight was used in calculating the different cross-sections.

It is usual to assume the section and compute the lines of pressure, or work them out graphically. The procedure followed in the Board of Water Supply was analytic, checked by the graphic method, wherein minimum sections were calculated directly as is done here, and then chosen ones were investigated. The formulas for design, which were adapted by the speaker from those which Mr. Wegmann early developed, contain conditions of uplift and ice pressure. It is not proposed to give all these formulas here; but the fundamental method of analysis will be indicated for those who may be unfamiliar with work of this kind. Formulas for investigation were also developed, and included other forces than those mentioned here.

In Fig. 7, *a-b*, or *l*, may represent the length of the dam base for a unit length of dam; and it may be divided into three parts, *y*, *v*, and *u*; *a* is the up-stream end of the joint. Let *W* represent the position of the weight of the mass of masonry acting through its center of gravity, horizontally distant *y* from *a*. Then the center of pressure when the dam is subject to the entire loading, both water pressure and uplift, or whatever is wished to be assumed, will be distant *v* from *W*,

and the remaining distance or segment of the base considered will be called u. We then have the equation, $l = y + v + u$. If moments be taken about e, the center of pressure of the resultant when the dam is subject to the loading, and M be that moment, tending to overturn the mass of the dam, M divided by W will equal v. Mr. Brodie.

We may substitute $\frac{M}{W}$ for v, in the equation for l, and then whatever may be the overturning moment due to any forces considered, and whatever the conditions due to the shape of the structure (that is, y may or may not be an assumed condition), and whatever limit or condition that is wished to be placed upon u (that is, the distance of

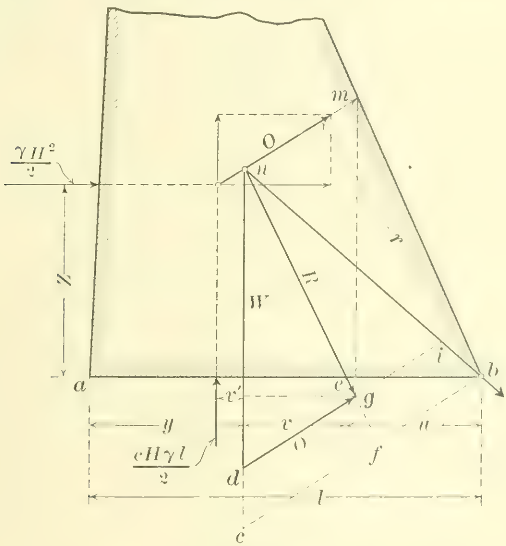


Fig. 7.

the center of pressure from the down-stream end of the joint), there will result an equation involving l. By substituting imposed conditions for y and u, and the loading, and then reducing, a quadratic equation is obtained, and this, being in terms of l, will then enable us to solve the base directly. Therefore, it is evident that, by introducing such conditions, there could be developed a series of appropriate equations for design. The governing conditions vary, as one goes from the top of a dam downward, so that these conditions have to be introduced successively; therefore, one simple working equation cannot be formed for the entire cross-section. That is all the speaker wishes to say as to the analysis at this stage, deeming it a sufficient indication of the methods of determining the sections which will now be presented.

Mr. Brodie. First, consider Section *A*, Fig. 6, which has a 10-ft. top, a 10-ft. super-elevation from the normal reservoir level, and a $41\frac{1}{2}$ ft. base. It resulted from the conditions of ice at the normal reservoir level and the resultant center of pressure at the middle-third point at each joint.

Second, Section *B* resulted in a 6-ft. top width and a 5-ft. super-elevation.

Third, Section *D* has a 5-ft. top width and a 5-ft. super-elevation.

Thus, the super-elevations are, respectively, 10 ft., 5 ft., and 5 ft.; with the bases, areas, etc., as recorded in Table 2.

The dam at Austin, Pa., was $2\frac{1}{2}$ ft. wide on the top, with a $2\frac{1}{2}$-ft. super-elevation; the down-stream face sloped down to 7 ft. from the up-stream face at 11 ft. below the top, and then battered off to 30 ft. at 44 ft. below the top, from which level it continued vertically down 6 ft. farther; its back was vertical for the full 50 ft.

The points wished to be brought out are these: By applying direct analytic solution methods, it was found that Section *A* had to have a super-elevation of 10 ft. The top had to be at least 10 ft. wide; by making it 15 ft., the line of the down-stream face, worked out, joined the face of the structure having a 10-ft. top, about 17 ft. below the water level, and continued thence with about the same slope as for the cross-section with the 10-ft. top, showing that there was not much advantage in increasing the width; but there is an advantage in having a super-elevation, especially for the ice pressure.

One would naturally infer that the top would be most affected by that thrust, and this is shown to be so by comparing Sections *A* and *B*, as determined. It will be recalled that Section *B* was calculated without ice-thrust conditions, but with uplift and the horizontal thrust of water on the back.

Section *B* required a lower top, in order to obtain a regular down-stream face. It will be noted, however, that this section differs from *A* in that the up-stream face of the latter is vertical. The series of batters forming this face for Section *B* resulted directly from the necessary application of the formulas containing the middle-third limit condition for reservoir empty, in this case, which did not govern in the case of Section *A*.

Section *C* is subjected to the same conditions as *B*, but with this difference: the super-elevation resulted in the vertical portion of the down-stream face being continued to a lower level than that of *B*; however, the effect of that vertical section on the resulting base lengths below was to throw the lower part of the cross-section well within that of *B* on the down-stream side and then throw it out, lower down, toward *B* and well without the up-stream surface of Section *B*.

As the cross-section is being calculated, proceeding from the top, with only uplift and the horizontal force due to the retained water

Mr. Brodie.

acting, it will be found that the resulting cross-section, while more slender at the top, will gradually extend down stream, requiring longer bases, as the determinations continue downward, than were required for the ice-pressure design. This means that at the upper part of the dam the ice thrust governs. (It should be said that, where the ice is disregarded, the head due to the reservoir at flood level is taken for the determination of Sections *B* and *C*.) It is evident, by referring to Fig. 6, that a point would be reached, if the design of the several cross-sections were continued downward, where the profile of either *B* or *C* would come out, crossing that of *A*, and give greater bases than Section *A*, at the same elevations. This shows the importance of designing for ice thrust in low dams, while flood-level conditions govern in high masonry dams.

In designing a high masonry dam, the procedure would be to start with the ice thrust condition and design a section between 80 and 100 ft. high (according to the usual assumptions and conditions, this inter-section of "ice" design and "flood level" design occurs at about 100 ft. from water level), and then start from the top again with the flood level conditions, and go down until a base of the "flood level" section becomes greater than that of the "ice thrust" design at the same elevation; then the remainder of the design is continued with the flood conditions, but with the ice level cross-section superimposed.

The areas of these various sections work out as follows: Section *A*, 1 475 sq. ft.; Section *B*, 992 sq. ft.; and Section *D*, 836 sq. ft.

The cross-section of the Austin Dam worked out to about 840 sq. ft., therefore, it will be seen that Section *D*, which had to meet only the horizontal thrust of the water retained, was practically equal to that of the Austin Dam. Section *A* was some 76% greater than Section *D*, which was used as a basis of comparison, while the uplift as assumed and the horizontal thrust of the water gave Section *B* some 19% greater area than *D*. Thus the economy of the provision for the different designs would be about 19% and 76%, for uplift alone, and for ice and uplift, respectively. This is with a moderate ice assumption.

Concerning Section *A*, another point of interest is that, with this ice design and with uplift, the angle of the resultant (the calculated angle that the resultant makes with the vertical) is only 28 degrees. The speaker believes that M. Lévy recognized 30°, and Professor Rankine 36°, as being the maximum limit. On the other hand, Section *B* had a resultant which made an angle of nearly 38° with the vertical, showing that this direct design for the middle-third condition, with horizontal water thrust and with uplift obtaining, proves unsatisfactory for the base at a level of 50 ft. below the top of the dam; for, while proving adequate for conditions against overturning and

Mr. Brodie.

maximum pressures, it does not meet the requirements imposed against sliding on the base.

At this point some general observations on the subject of "the factor against overturning" will be made.

There is a difference between the values obtained for the so-called "factor of safety" against overturning, according to whether a ratio of one set of moments, or of another, is taken when uplift is assumed. The first set of moments compared would be the "resisting moment" and the moment of forces tending to overturn the structure. On the other hand, the ratio of the resultant moment of the vertical to the resultant moment of the horizontal components of the forces could be taken.

By referring again to Fig. 7, it will be seen that, for example, the horizontal water pressure on the back, $\frac{\gamma H^2}{2}$, the uplift, $\frac{c\,H\gamma\,l}{2}$, and the weight of the masonry, W, constitute the forces, with the reaction (not shown) considered as acting on the dam. (See *"Nomenclature."*)

The forces tending to overturn the dam about the toe at b are $\frac{\gamma H^2}{2}$ and $\frac{c\,H\gamma\,l}{2}$, the resultant of which is denoted in magnitude and direction by the line, O, at the normal distance, r, from b. The force resisting this tendency is W, the line of action of which is normally distant $(u + v)$ from b. If $n\,m$ denotes the force, O, in magnitude and direction, and $n\,d$, the force, W, then $n\,g$ will represent, in magnitude and direction, the force, R, or the final resultant of all the forces, which is opposed by the reaction (for equilibrium to be assured) at the point, e, distant u from b.

The resisting moment about b, then, is $W\ (u + v) = M_0$ while the overturning moment about the same point is

$$r\,O = M^1 \quad \frac{\gamma\,H^2}{2} \times z + \frac{c\ H\gamma\ l}{2}\ (u + v + v^1) = M_1 + M_2.$$

Whence, for the ratio of "resisting moment to overturning moment" there may be written:

$$\frac{M_0}{M^1} = \frac{M_0}{M_1 + M_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

and for the ratio of the "resultant moment of the vertical components" to the "resultant moment of the horizontal components" of the forces there follows:

$$\frac{M_0 - M_2}{M_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

These two expressions for the "factor" evidently become equal to each other only when $M_2 = 0$, or when uplift is ignored; also, when the factor of safety is equal to unity (when $M_0 - M_2 = M_1$), or at the point of overturning. Therefore, the usual expression, $\frac{u + v}{v}$, will

not be the value for the "factor of safety" against overturning according to Equation a. Mr. Brodie.

To consider the foregoing discussion for the purpose of developing a graphic treatment for determining the value in either case, it must be remembered that, for the dam to be on the point of overturning, the ratio of the two moments, M_0 and M^1 of Equation a, must equal unity, or $M_0 = M_1 + M_2$, and the line of action, R, in Fig. 7, must pass through b. Inasmuch as W is constant, one or all of the other forces may at this stage be considered variable, in order to bring about the above supposititious condition. According to Equation a the distance, r, is constant, and the water pressure on the back and the uplift, therefore, are supposed to be proportionately increased to fulfill this condition of bringing the line of action, R, through b. This seems reasonable from the fact that the horizontal water thrust cannot be considered to increase without a corresponding increase in the uplift. Therefore, the condition necessary to bring the resultant, R, through b instead of through e, where it actually falls, is that $O = d\ g$ be increased to $d\ i$, in Fig 7. If $b\ c$ be drawn through b, parallel to O (and, therefore, to $d\ g$), the ratio sought follows from the similarity of the triangles, $n\ i\ d$ and $n\ b\ e$, or, the factor of safety, with respect to resisting moment and overturning moment, is equal to the ratio, $\frac{d\ i}{d\ g} = \frac{e\ b}{e\ f}$.

The foregoing conception, Equation b, of the "factor of safety" tacitly assumes that only the horizontal thrust of the water is instrumental in moving the center of pressure from e to b, and that the uplift merely lessens the resisting moment.

As the overturning force to be increased is therefore horizontal, and as the length of the line parallel to the overturning resultant and comprehended between the point, b, and the line of action of the resisting force is divided by its segment (comprehended between the actual resultant and the same line of action of the resisting force) to get the ratio, or factor against overturning, it at once follows that the division according to Equation b would be $\frac{u + r}{r}$. Equation a seems preferable, or the "factor of safety" $= \frac{e\ b}{e\ f}$, as in Fig. 7. The "factor of safety," however, is of doubtful value, due to the certain impossibility of the structure's rotation about the point, b; but it may be a useful quantity for comparison at times. The expression (a) may give values less than (b) by as much as one-third, in some cases.

The detailed results of calculations determining the computed sections, A, B, C, and D, of Fig. 6, are given in Table 3; the symbols used therein being fully explained under the subsequent heading, "*Nomenclature.*"

Mr. Brodie.

TABLE 3.—DETAILED RESULTS OF CALCULATIONS DETERMINING THE COMPUTED SECTIONS, A, B, C, AND D.

($c = \frac{2}{3}$; $\Delta = 2\frac{1}{4}$; $6\ T = 2\ 064$.)

Computed cross-section.	Joint No.	H (Head).	H^3	h in feet.	$H + a$ (height).	A_0 in square feet.	A in square feet.	l_0 in feet.	l_0^2	l in feet.	y_0 in feet.	y in feet.	u in feet.	t in feet.	$A_0\ y_0$
A (Read H and a, H_1 and a_1.)	1	8.5	615	18.5	18.5	....	275.5	10.0	100.0	19.8	....	7.7	$\frac{l}{3}$	....	....
	2	19.5	7 440	11.0	29.5	275.5	528.9	19.8	392.5	26.2	7.7	9.6	"	....	2 130
	3	30.5	28 400	11.0	40.5	528.9	849.4	26.2	690.0	32.0	9.6	11.5	"	....	5 070
	4	47.5	107 170	17.0	57.5	849.4	1 475.0	32.0	1 024.0	41.5	11.5	14.5	"	....	9 760
B	1_b	9.1	....	....	11.6	....	69.6	6.0	....	6.0	....	3.0	$\frac{l}{3}$	....	....
	3	33.0	35 937	23.9	35.5	69.6	439.6	6.0	36.0	25.0	3.0	$\frac{l}{3}$	"	1.05	....
	4	50.0	125 000	17.0	52.5	439.6	992.1	25.0	625.0	40.0	$\frac{l}{3}$	$\frac{l}{3}$	"	0.61	....
												$t_3 + t_4$	=	1.66	
C	1_c	16.2	....	....	23.7	....	237.0	10.0	....	10.0	....	5.0	$\frac{l}{3}$	....	....
	3	33.0	35 937	16.8	40.5	237.0	491.0	10.0	100.0	20.3	5.0	$\frac{l}{3}$	"	1.12	...
	4	50.0	125 000	17.0	57.5	491.0	999.0	20.3	412.0	39.5	$\frac{l}{3}$	$\frac{l}{3}$	"	2.75	...
												$t_3 + t_4$	=	3.87	
D	1	11.0	1 331	13.5	13.5	0	75.2	5.0	25.0	6.2	....	2.8	$\frac{l}{3}$	...	.
	3	33.0	35 937	22.0	35.5	75.2	375.0	6.2	38.0	21.1	2.8	$\frac{l}{3}$	"	0.9	.
	4	50.0	125 000	17.0	52.5	375.0	836.0	21.1	446.0	33.1	$\frac{l}{3}$	$\frac{l}{3}$	"	0.4	
												$t_3 + t_4$	=	1.3	

As brief a statement as possible of the formulas mentioned earlier by the speaker follows. Of these formulas, the following were necessary for determining Sections *A, B, C,* and *D:* Mr. Brodie

For Section A, Series D.—Stage I was first used, but a few trial substitutions (necessary because of the form of expression) conclusively showed that only Stage II applied here.

For Section B, Series C.—Stage I applied; but, after using Stage II and calculating y, by supplementary formula, it was found necessary to proceed to Stage III for the calculation of Joints 3 and 4.

For Section C, Series C.—Stage I was used for Joint 1_c, and Stage III for Joints 3 and 4.

For Section D, Series A.—Stage I was used, as for Section *A*, and with the same conclusion, except that Stage II applied only to the determination of Joint 1, after which Stage III applied

(It may be stated here that the speaker has used Series *B* satisfactorily, with only the thrust condition, for the rapid determination of bridge abutment dimensions.)

Six series of formulas* will be given and designated by the letters *A, B, C, D, E,* and *F,* respectively. Each series conforms to a given set of conditions with respect to external forces.

Series *F* forms a set of general equations for the condition of water overtopping the dam.

Nomenclature.—The following nomenclature will apply to the formulas: "Toe" or "Front" will signify the down-stream face; "Heel" or "Back" will signify the up-stream face. All linear distances are expressed in feet, and all areas in square feet. In connection with the following see Figs. 8 to 13.

L = the width of the top of the dam cross-section;

l = the length of a horizontal joint of masonry, to be determined;

l_0 = the known length of the joint next above the joint of length l;

h = the depth of a course of masonry (the vertical distance between l_0 and l);

P = the line of pressure, reservoir full;

P' = the line of pressure, reservoir empty;

u = the distance from the front edge of the joint, l, to the point of intersection of P with the joint, l, measured parallel to the joint, l;

y = the distance from the back edge of the joint, l, to the point of intersection of P' with the joint, l, measured parallel to the joint, l;

* The demonstration may be found in "High Masonry Dam Design," by C. E. Morrison and O. L. Brodie, Associate Members, Am. Soc. C. E.

Mr. Brodie.

y_0 = the distance from the back edge of the joint, l_0, to the point of intersection of P' with the joint, l_0, measured parallel to the joint, l_0 ;

v = the distance between P and P' at the joint, l, measured parallel to the joint, l;

γ = the weight of a cubic foot of water, in pounds (62.5 lb.);

γ' = the weight of a cubic foot of mud, in pounds (75 to 90 lb.);

$\varDelta$ = the ratio of the unit weight of masonry to the unit weight of water ;

$\varDelta\gamma$ = the weight of a cubic foot of masonry, in pounds ;

H = the head of water on the joint, l (vertical distance of the joint, l, below the water surface);

H' = the depth of the earth back-fill over the joint, l, on the front ;

H_1 = the head of water on the joint, l, when ice acts at the surface of the water ;

$H - H_1$ = the rise of the water level, due to flood, waves, etc., above the normal level for full reservoir ;

h_1 = the head of water above the mud level (liquid mud of weight, γ');

h_2 = the head of liquid mud on the joint, l, on the back ;

a = the vertical distance from the top of the dam to the surface of the water (flood);

a_1 = the vertical distance from the top of the dam to the surface of the water when ice is considered (a_1 generally exceeds a);

b = the vertical distance from the water surface to the top of the dam when the dam is overtopped ;

c = the ratio of upward thrust intensity due to hydrostatic head, H (or H_1, or $h_1 + h_2$) assumed to act at the heel of the joint, l (assumed as $\frac{2}{3}$);

$T\gamma$ = the horizontal ice thrust at the water surface, in pounds ;

$D\gamma$ = the horizontal dynamic thrust of the water, in pounds ;

$E\gamma$ = the thrust of the earth back-fill, in pounds (on front);

$W_v\gamma$ = the vertical pressure on the inclined up-stream face above the joint, l, in pounds ;

A_0 = the total area of the cross-section of the dam above the joint, l_0 ;

A = the total area of the cross-section of the dam above the joint, l ;

t = the batter of the up-stream face for the vertical distance, h ;

s = the distance of the line of action of $W_r y$ from the up-stream edge of the joint, l, measured parallel to the joint, l; Mr. Brodie.

δ = the angle that $E\gamma$ makes with the horizontal;

α = the angle of slope of the down-stream face of the dam with the horizontal;

β = the angle R makes the vertical;

p = the maximum allowable pressure intensity at the toe, in pounds per square foot;

q = the maximum allowable pressure intensity at the heel, in pounds per square foot (p is assumed less than q), p and q may be used to signify the calculated, existent pressure intensities corresponding to P and P', respectively, for the joint, l;

$F = \dfrac{\gamma H^2}{2}$ = the horizontal static thrust of the water, in pounds;

$W = A\ \Delta\gamma$ = the total weight of masonry resting on the joint, l, in pounds;

$W_0 = A_0 \Delta\gamma$ = the total weight of masonry resting on the joint, l_0, in pounds;

R = the resultant;

R' = the resultant of the reactions;

$\dfrac{cHl\gamma}{2}$ = the upward thrust of the water on the base, l.

In Figs. 8 to 12, inclusive, hydrostatic pressures are indicated by triangular and trapezoidal areas included within dotted lines. Ice pressure is indicated to contrast H_1 with H.

As before, a unit length of 1 ft. of dam will be considered. Then the letters, T, D, E, W_r, A, A_0, and H^2 would signify volumes.

It will be observed that, where possible, the several equations will have been cleared of the term $\Delta\gamma$ (thereby simplifying actual calculations).

It will be recalled that the fundamental expression for finding the length, l, of any joint involves M, which must in each case signify the total overturning moment.

The development of a cross-section, by any one of the following series of equations may comprise five stages, each stage representing the introduction of a governing condition. Hence, for each stage, there obtains a main equation for finding the length of the joint, l, each main equation being supplemented by secondary equations for y, u, and t; p and q.

It may be necessary to use more than one of the series of equations in determining a cross-section.

Mr. Brodie.

For ready reference, the five stages will be set forth and depicted in order as follows:

Stages in Development.

Stage I.—This stage extends from the top of the dam to the joint where the front face commences to batter. It is the rectangular section. $y \geqq \frac{1}{3} L$; $u \geqq \frac{1}{3} L$ (see Fig. 8). (Ice pressure is purposely omitted in Fig. 8 to prevent a confusion of letters in a small space.)

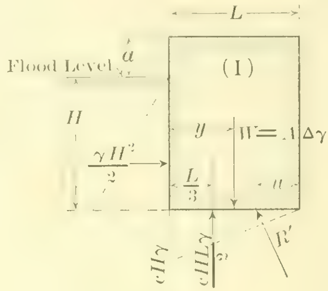


Fig. 8.

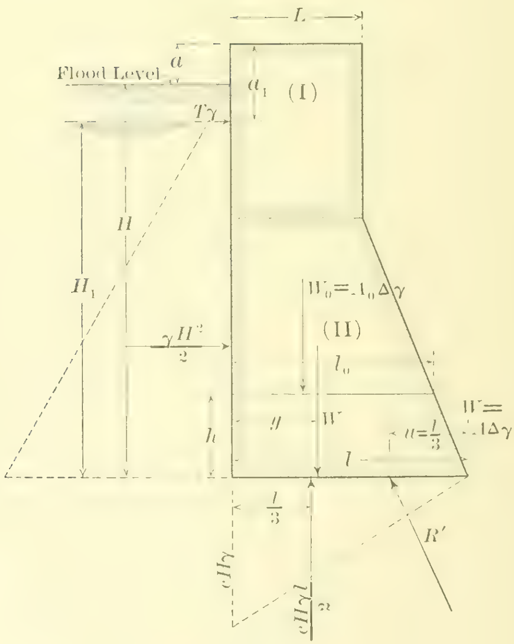


Fig. 9.

Stage II.—This stage extends from the lower limit of Stage I to the point where the back face commences to batter. $u = \frac{1}{3}\,l$, $y \geqq \frac{1}{3}\,l$ (see Fig. 9). Mr. Brodie.

Stage III.—This stage extends from the lower limit of Stage II to the point where the intensity of pressure on the toe has reached the maximum allowable intensity. In this stage, $u = \frac{1}{3}\,l$; $y = \frac{1}{3}\,l$ (see Fig. 10).

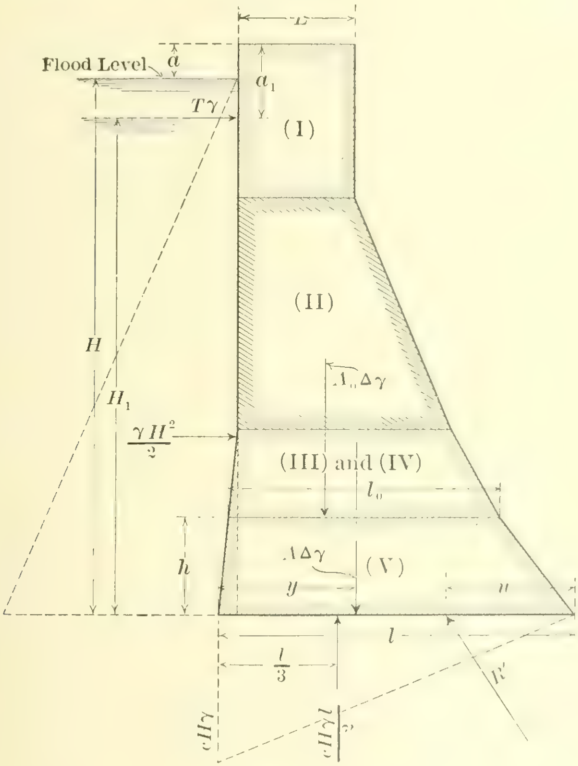


FIG. 10.

Stage IV.—This stage extends from the lower limit of Stage III to the point where the pressure intensity on the heel has reached the maximum allowable intensity. For this stage $u > \frac{1}{3}\,l$; $y = \frac{1}{3}\,l$. (See Fig. 10.)

Stage V.—In this stage the limiting intensities of pressure at both toe and heel having been reached, $y > \frac{1}{3}\,l$; $u > \frac{1}{3}\,l$. It extends from the lower limit of Stage IV downward. (See Fig. 10.)

Mr. Brodie. The following secondary formulas, supplementary to the main equations of all series, with substitutions as noted, are arranged in order corresponding with the preceding.

Equations Supplementary to All Series.

	With condition of hydrostatic upward pressure on base obtaining, substitute the formulas in this column in place of those corresponding, as indicated.
Stage I.	
$u \geqq \frac{1}{3} L$	
$y = \frac{1}{2} L$	
$t = 0$	
$p = \frac{2 \Delta \gamma A}{L} \left(2 - \frac{3u}{L}\right)$	$p = \gamma \left(\frac{2 \Delta A}{L} - c H\right) \left(2 - \frac{3u}{L}\right)$
$q = \frac{\Delta \gamma A}{L}$	
Stage II.	
$u = \frac{1}{3} l$	
$y = \dfrac{A_0 y_0 + (l^2 + l l_0 + l_0^2) \frac{h}{6}}{A_0 + \left(\frac{l + l_0}{2}\right) h}$	
$t = 0$	
$p = \frac{2 \Delta \gamma A}{l}$	$p = \gamma \left(\frac{2 \Delta A}{l} - c H\right)$
$q = \frac{2 \Delta \gamma A}{l} \left(2 - \frac{3y}{l}\right)$	
Stage III.	
$u = \frac{1}{3} l$	
$y = \frac{1}{3} l$	
$t = \dfrac{2 A_0 (l - 3 y_0) - h l_0^2}{6 A_0 + h (2 l_0 + l)}$	
$p = \frac{2 \Delta \gamma A}{l}$	$p = \gamma \left(\frac{2 \Delta A}{l} - c H\right)$
$q = \frac{2 \Delta \gamma A}{l}$	
Stage IV.	
$u = \frac{2}{3} l - \frac{p l^2}{6 \Delta \gamma A}$	$u = \frac{2}{3} l - \frac{p l^2}{3 \gamma (2 \Delta A - c H l)}$
$y = \frac{1}{3} l$	
$t = \dfrac{2 A_0 (l - 3 y_0) - h l_0^2}{6 A_0 + h (2 l_0 + l)}$	

Equations Supplementary to All Series—(*Continued*).

Mr. Brodie.

With condition of hydrostatic upward pressure on base obtaining, substitute the formulas in this column in place of those corresponding, as indicated.

$$p = \frac{2\,\Delta\gamma\,A}{l}\left(2 - \frac{3\,u}{l}\right) \text{ (limiting intensity)} \qquad\qquad p = \gamma\left(\frac{2\,\Delta\,A}{l} - c\,H\right)\left(2 - \frac{3\,u}{l}\right)$$

$$q = \frac{2\,\Delta\gamma\,A}{l}$$

Stage V.

$$u = \tfrac{2}{3}\,l - \frac{p\,l^2}{6\,\Delta\gamma\,A} \qquad\qquad u = \tfrac{2}{3}\,l - \frac{p\,l^2}{3\,\gamma\,(2\,\Delta\,A - c\,H\,l)}$$

$$y = \tfrac{2}{3}\,l - \frac{q\,l^2}{6\,\Delta\gamma\,A}$$

$$t = \frac{A_0\,(4\,l - 6\,y_0) + \left(h - \dfrac{q}{\Delta\gamma}\right)l^2 + (l - l_0)\,h\,l_0}{6\,A_0 + h\,(2\,l_0 + l)}$$

$$p = \frac{2\,\Delta\gamma\,A}{l}\left(2 - \frac{3\,u}{l}\right) \text{ (limiting intensity)} \qquad\qquad p = \gamma\left(\frac{2\,\Delta\,A}{l} - c\,H\right)\left(2 - \frac{3\,u}{l}\right)$$

$$q = \frac{2\,\Delta\gamma\,A}{l}\left(2 - \frac{3\,y}{l}\right) \text{ (limiting intensity)}$$

If T enters the following formulas, H (above) becomes H_1 (see Figs. 9 and 10).

Series A.

Overturning moment due to horizontal static water pressure on back of dam only.

Stage I.

$$H = \sqrt[3]{\Delta\,L^2\,(H + a)}.$$

Stage II.

$$l^2 + \left(\frac{4\,A_0}{h} + l_0\right)l = \frac{1}{h}\left(\frac{H^3}{\Delta} + 6\,A_0\,y_0\right) + l_0^2.$$

Stage III.

$$l^2 + \left(\frac{2\,A_0}{h} + l_0\right)l = \frac{H^3}{\Delta\,h}.$$

Stage IV.

$$l^2 = \frac{\gamma\,H^3}{p}.$$

Stage V.

$$\left(\frac{p + q}{h\,\Delta\gamma} - 1\right)l^2 - \left(\frac{2\,A_0}{h} + l_0\right)l = \frac{H^3}{\Delta\,h}.$$

Series B.

Overturning moment due to:

(*a*) Horizontal static water pressure on back, and

(*b*) Ice pressure applied at distance, a_1, from top.

Mr. Brodie.

Stage I.

$$H_1 = \sqrt[3]{\Delta (H_1 + a_1) L^2 - 6 T H_1}.$$

Stage II.

$$l^2 + \left(\frac{4 A_0}{h} + l_0\right) l = \frac{1}{h} \left(\frac{H_1^3 + 6 T H_1}{\Delta} + 6 A_0 y_0\right) + l_0^2.$$

Stage III.

$$l^2 + \left(\frac{2 A_0}{h} + l_0\right) l = \frac{1}{\Delta h} \left(H_1^3 + 6 T H_1\right).$$

Stage IV.

$$l^2 = (H_1^3 + 6 T H_1) \frac{\gamma}{p}.$$

Stage V.

$$\left(\frac{p + q}{h \Delta \gamma} - 1\right) l^2 - \left(\frac{2 A_0}{h} + l_0\right) l = \frac{1}{\Delta h} (H_1^3 + 6 T H_1).$$

SERIES C.

Overturning moment due to:

(*a*) Horizontal static water pressure on back.

(*b*) Upward water pressure on base. Pressure intensity decreasing uniformly from $c H \gamma$ at heel to zero intensity at toe.

Stage I.

$$H = \sqrt[3]{L^2 [\Delta (H + a) - c H]}.$$

Stage II.

$$\left(1 - \frac{c H}{\Delta h}\right) l^2 + \left(\frac{4 A_0}{h} + l_0\right) l = \frac{1}{h} \left(\frac{H^3}{\Delta} + 6 A_0 y_0\right) + l_0^2.$$

Stage III.

$$\left(1 - \frac{c H}{\Delta h}\right) l^2 + \left(\frac{2 A_0}{h} + l_0\right) l = \frac{H^3}{\Delta h}.$$

Stage IV.

$$l^2 = \frac{\gamma H^3}{p}.$$

Stage V.

$$\left(\frac{p + q}{h \Delta \gamma} - 1\right) l^2 - \left(\frac{2 A_0}{h} + l_0\right) l = \frac{H^3}{\Delta h}.$$

SERIES D.

Overturning moment due to:

(*a*) Horizontal static water pressure on back (head $= H_1$).

(*b*) Ice pressure applied at distance, a_1, from top.

(*c*) Upward water pressure on base. Pressure decreasing uniformly from $c H_1 \gamma$, at heel to zero intensity at toe.

Stage I.

$$H_1 = \sqrt[3]{L^2 [(H_1 + a_1) \Delta - c H_1] - 6 T H_1}.$$

Mr. Brodie.

Stage II.

$$\left(1 - \frac{c\,H_1}{2\,h}\right) l^2 + \left(\frac{4\,A_0}{h} + l_0\right) l$$
$$= \frac{1}{h}\left(\frac{H_1^3 + 6\,T\,H_1}{2} + 6\,A_0 y_0\right) + l_0^2.$$

Stage III.

$$\left(1 - \frac{c\,H_1}{2\,h}\right) l^2 + \left(\frac{2\,A_0}{h} + l_0\right) l = \frac{1}{2\,h}(H_1^3 + 6\,T\,H_1).$$

Stage IV.

$$l^2 = \frac{\gamma\,(H_1^3 + 6\,T\,H_1)}{p}.$$

Stage V.

$$\left(\frac{p + q}{h\,2\gamma} - 1\right) l^2 - \left(\frac{2\,A_0}{h} + l_0\right) l = \frac{H_1^3 + 6\,T\,H_1}{2h}.$$

SERIES E.

Ice pressure neglected in Fig. 11. Overturning moment due to:

(*a*) Horizontal static water pressure on back (head $= h_1$).

(*b*) Ice pressure applied at distance, a_1, from top.

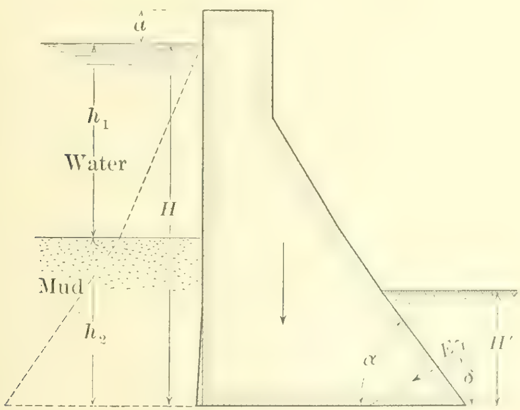


FIG. 11.

(*c*) Upward water pressure on base; pressure intensity decreasing uniformly from $c(h_1 + h_2)\gamma$ at heel to zero intensity at toe.

(*d*) Mud (liquid) pressure on back (head h_2), commencing at distance, h_2, above joint in question. Weight of mud $= \gamma'$. As before, if T be equated to zero, a_1 becomes equal to a in formulas.

Mr. Brodie.

Stage I.—(h_1 of known value, h_2 to be determined).

$$\frac{h_2^3 \gamma'}{\gamma} + (h_1 + h_2)\left[3 h_1 h_2 + 6 T + L^2 (c - \Delta)\right] = L^2 a_1 \Delta - h_1^3.$$

Stage II.

$$\left[1 - \frac{c(h_1 + h_2)}{\Delta h}\right] l^2 + \left(\frac{4 A_0}{h} + l_0\right) l = \frac{1}{\Delta h}\left[(h_1 + h_2)(3 h_1 h_2 + 6 T) + h_1^3 + \frac{h_2^3 \gamma'}{\gamma} + 6 A_0 y_0 \Delta\right] + l_0^2.$$

For trapezoidal section at top, make $A_0 = 0$, and $y_0 = 0$, and $l_0 = L$ in Stage II. This applies generally.

Stage III.

$$\left[1 - \frac{c(h_1 + h_2)}{\Delta h}\right] l^2 + \left(\frac{2 A_0}{h} + l_0\right) l = \frac{1}{\Delta h}\left[(h_1 + h_2)(3 h_1 h_2 + 6 T) + h_1^3 + \frac{h_2^3 \gamma'}{\gamma}\right].$$

Stage IV.

$$l^2 = \frac{\gamma}{p}\left[(h_1 + h_2)(3 h_1 h_2 + 6 T) + h_1^3 + \frac{h_2^3 \gamma'}{\gamma}\right].$$

Stage V.

$$\left(\frac{p + q}{h \Delta \gamma} - 1\right) l^2 + \left(\frac{2 A_0}{h} + l_0\right) l = \frac{1}{\Delta h}\left[(h_1 + h_2)(3 h_1 h_2 + 6 T) + h_1^3 + \frac{h_2^3 \gamma'}{\gamma}\right].$$

Series F.

This series consists of general formulas for a number of imposed conditions of loading. For any given case, the terms or factors expressing those conditions not appertaining must be eliminated by equating them to zero. (See Fig. 12.)

Conditions for General Formulas.—Overturning moment due to:

(*a*) Horizontal static water pressure on back (head $= h_1$).

(*b*) Upward water pressure on base; pressure intensity decreasing uniformly from $c H\gamma$, or $c (h_1 + h_2)\gamma$, at heel to zero intensity at toe.

(*c*) Mud (liquid) pressure on back (head h_2) as before.

(*d*) Dynamic pressure of water, $D\gamma$.

(*e*) Water flowing over top of dam, weight of water, of depth b, on top of dam being neglected.

*For condition of water not overtopping dam, $b = 0$ and $D = 0$.

* For water surface below top of dam, Series E, containing a, must be used.

Mr. Brodie.

For condition of no dynamic pressure, $D = 0$.

For condition of no upward water pressure, $c = 0$.

For condition of no mud (that is, mud being replaced by water) make $h_2 = 0$, $h_1 = H$.

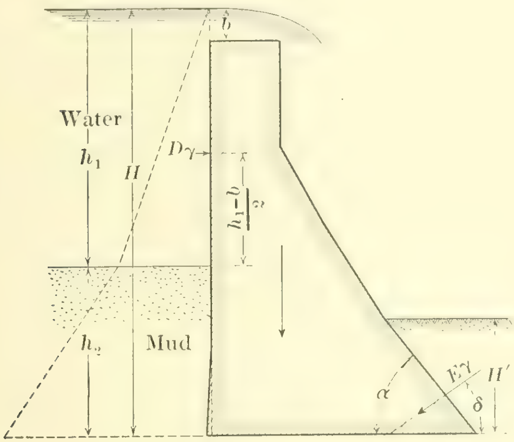


FIG. 12.

Stage I.—Rectangular cross-section at top, or rectangular dam, $l = l_0 = L$. This may fall under either of two cases, namely:

Case (1)

Condition: $h_1 = H$; $h_2 = 0$.

$$H^3 + H\,[+ 3\,D - 3\,b^2 + L^2\,(c - \Delta\,)] = b\,(3\,D - 2\,b^2 - L^2\,\Delta).$$

Case (2)

Condition: h_1 of known value; h_2 to be determined.

$$\frac{h_2^3\,\gamma'}{\gamma} + 3\,D\,h_2 + (h_1 + h_2)\,[3\,h_1\,h_2 + 3\,D - 3\,b^2 + L^2\,(c - \Delta)]$$
$$= b\,(3\,D - 2\,b^2 - L^2\,\Delta) - h_1^3.$$

As in the preceding series, the value of H or h_2, of Stage I, may be determined by several successive trial substitutions.

Stage II.—(*a*) Trapezoidal cross-section at top of dam or trapezoidal dam (spillway) front face battered. ($\Delta_0 = 0$, $l_0 = L$, and $y_0 = 0$.) Note: For a triangular dam, $l_0 = 0$, also.

$$\left[1 - \frac{c\,(h_1 + h_2)}{\Delta\,h}\right] l^2 + L\,l = \frac{1}{\Delta\,h}\Big[(h_1 + h_2)\,(3\,h_1\,h_2 \quad 3\,b^2)$$
$$+ h_1^3 + \frac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 \quad b)\Big] + L^2.$$

Mr. Brodie.

(*b*) Trapezoidal section continued (front face battered).

$$\left[1 - \frac{c\,(h_1 + h_2)}{\Delta\, h}\right] l^2 + \left(\frac{4\,A_0}{h} + l_0\right) l = \frac{1}{\Delta\, h}\Big[(h_1 + h_2)$$

$$(3\,h_1\,h_2 - 3\,b^2) + h_1^3 + \frac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 - b)$$

$$+ 6\,A_0\,y_0\,\Delta\Big] + l_0^2.$$

Stage III.—Both faces battered.

$$\left[1 - \frac{c\,(h_1 + h_2)}{\Delta\, h}\right] l^2 + \left(\frac{2\,A_0}{h} + l_0\right) l = \frac{1}{\Delta\, h}\Big[(h_1 + h_2)$$

$$(3\,h_1\,h_2 - 3\,b^2) + h_1^3 + \frac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 - b)\Big].$$

Stage IV.—Limiting intensity of pressure, *p*, introduced.

$$l^2 = \frac{\gamma}{p}\Big[(h_1 + h_2)\,(3\,h_1\,h_2 - 3\,b^2) + h_1^3$$

$$+ \frac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 - b)\Big].$$

Stage V.—Limiting intensities, *p* and *q*.

$$\left(\frac{p + q}{h\,\Delta\,\gamma} - 1\right) l^2 - \left(\frac{2\,A_0}{h} + l_0\right) l = \frac{1}{\Delta\, h}\Big[(h_1 + h_2)\,(3\,h_1\,h_2 - 3\,b^2)$$

$$+ h_1^3 + \frac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 - b)\Big].$$

The increased number of overturning loads, then, tend to render the right-hand members of the various equations more involved; though, after a little practice, one may easily carry through a design with surprising rapidity. The slide rule may be used to great advantage, and it is suggested that the results be tabulated as determined, in some such form as the values for Sections *A, B, C,* and *D,* in Table 3.

The effect on the calculation of a cross-section of back-fill on the down-stream face, of course, could be cared for by introducing that condition into the preceding series of equations; but as this effect, as computed, would be, in any case, largely dependent on assumptions which may vary widely, and, as the placing of back-fill is generally a later consideration with respect to construction, the propriety of such introduction at that stage of design is questionable.

In the following formulas for investigation, therefore, the general conditions of an earth thrust acting at the down-stream face, and of a vertical component of thrust of material on the up-stream, inclined face of the dam are introduced.

By any of these formulas, the position of the line of resistance for any given cross-section and respective conditions may be determined with regard to any horizontal joint and its down-stream edge, the value of *u* being the quantity sought.

Mr. Brodie.

Any condition may be disregarded by equating its term to zero. The first expression below contains all the conditions heretofore considered, with the additional ones just stated; and from it follow the succeeding expressions for u. It should be remembered that the term, T, cannot be co-existent in any expression for stability with b, and therefore with D. Nevertheless, all these terms are written with the understanding that the proper eliminations be always made. Three general group equations will be written.

Formulas for Investigation.

First, Conditions of retained mud, water, overtopping, etc.—(See Fig. 12).

$$u = l - y - \frac{\left\{ \begin{array}{l} (h_1 + h_2)\,[3\,h_1 h_2 + 6\,T - 3\,b^3 + c\,l\,(3\,y - l)] + h_1^3 \\ \quad + \dfrac{h_2^3\,\gamma'}{\gamma} + 2\,b^3 + 3\,D\,(h_1 + 2\,h_2 - b) - 6\,W_r\,(y - s) \\ \qquad + 6\,E\left[(l - y)\sin.\,\delta - \dfrac{H'}{3}\,\dfrac{\sin.\,(\delta + \alpha)}{\sin.\,\alpha}\right] \end{array} \right\}}{6\,(W_r + E\sin.\,\delta + A\,\Delta) - 3\,c\,(h_1 + h_2)\,l}.$$

Whence, for conditions of retained mud, water, etc., but no overtopping, by making $b = 0$ and $D = 0$, there follows (see Fig. 11),

$$u = l - y - \frac{\left\{ \begin{array}{l} (h_1 + h_2)\,[3\,h_1\,h_2 + 6\,T + c\,l\,(3\,y - l)] + h_1^3 + h_2^3\,\dfrac{\gamma'}{\gamma} \\ \quad - 6\,W_r\,(y - s) + 6\,E\left[(l - y)\sin.\,\delta - \dfrac{H'}{3}\,\dfrac{\sin.\,(\delta + \alpha)}{\sin.\,\alpha}\right] \end{array} \right\}}{6\,(W_r + E\sin.\,\delta + A\,\Delta) - 3\,c\,(h_1 + h_2)\,l}.$$

From this last expression for u, for conditions of retained water, etc., but neither mud nor overtopping, by making $h_1 = H_1$, $h_2 = 0$, there is obtained:

$$u = l - y - \frac{\left\{ \begin{array}{l} 6\,T + H_1^2 + c\,l\,(3\,y - l) - \dfrac{6\,W_r}{H_1}\,(y - s) \\ \quad + \dfrac{6\,E}{H_1}\left[(l - y)\sin.\,\delta - \dfrac{H'}{3}\,\dfrac{\sin.\,(\delta + \alpha)}{\sin.\,\alpha}\right] \end{array} \right\}}{6\left(\dfrac{W_r + E\sin.\,\delta + A\,\Delta}{H_1}\right) - 3\,c\,l}.$$

As in equations for design, when $T = 0$, $H_1 = H$. If H' is of such depth that the down-stream batter of the cross-section varies considerably, an approximate solution is possible by assuming some average batter for the lower portion. The expression for the earth thrust is general, as is seen. After u is determined for each joint, the intensities of maxima pressures can be determined for the given cross-

Mr. Brodie. section, the general expression for p, corresponding to the above expressions for u, being:

$$p = \frac{2\,\gamma}{l}\left[W_v + E \sin.\,\delta + A\,\Delta - \frac{c\,(h_1 + h_2)\,l}{2}\right]\left(2 - \frac{3\,u}{l}\right).$$

In connection with the computation for the value of y in an investigation, as indicated above, it is necessary to obtain the position of the centroid of a trapezoid with respect to the back, or up-stream edge of the joint in question. The following expression for x, in connection with Fig. 13, may prove convenient:

$$x = \frac{(l^2 + l\,l_0 + l_0^2) + t\,(l + 2\,l_0)}{3\,(l + l_0)}.$$

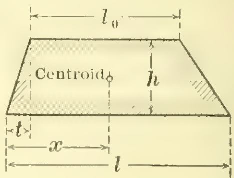


Fig. 13.

If it is desirable to consider tension as active in the joint, and if p_t' is the intensity, in tons per square foot, at the down-stream end of the joint, and p_t'' is the intensity at the up-stream edge of the joint, p, above, which, as written, is in pounds per square foot, will take the form:

$$p_t' = \frac{1}{16\,l}\left[W_v + E \sin.\,\delta + A\,\Delta - \frac{c\,(h_1 + h_2)\,l}{2}\right]\left[2 - \frac{3\,u}{l}\right]$$

and

$$p_t'' = \frac{1}{16\,l}\left[W_v + E \sin.\,\delta + A\,\Delta - \frac{c\,(h_1 + h_2)\,l}{2}\right]\left[\frac{3\,u}{l} - 1\right].$$

In the case where there is liquid mud only on the back, W_v becomes equal to $\frac{A'\,\gamma'}{\gamma}$, where A' is the area of the superimposed mud.

Mr. Dunham. H. F. Dunham, M. Am. Soc. C. E. (by letter).—Since the failure of the dam at Austin, Pa., the author and a large number of contributors to technical journals appear to agree on two important considerations. The author, in tersest English, voices his own and the ideas of all those writers, as follows:

"The effect of this upward pressure, however, must be counteracted, either by increasing the section of the dam or by increasing its height above the water level in the reservoir, or by both."

It is the writer's purpose to hint at a third method of counteracting upward pressure. Its value can be compared with the two first named. There can be no question that a dam should have a good foundation. Firm and impervious rock should always be safe and satisfactory. Strong, tough, and pervious rock should also be safe and fairly satisfactory, provided it affords a good anchorage. Thin layers of stone, and silt or mud, are excluded from this definition.

It often happens that water under pressure passes through a block of sandstone in quantity sufficient to make, not a brook, but a small stream. No one is disturbed, however, by any fear of cleavage,

Mr. Dunham

splitting, or other fracture of the block, because he knows that the cohesive strength of the stone is greatly in excess of the disrupting force of the water. As a matter of fact, the resistance of the block to overturning increases with the presence of the water in the porous stone, for the weight is increased. Imagine such a block to be extended in dimensions until it is large enough for an Austin Dam or a New Croton Dam. Would it be in the least degree unsafe, provided the tensile strength of the stone was still in excess (by a proper safety factor) of the bursting force of the water, and provided, of course, that it was held to the foundation rock by equally cohesive anchorage?

In Boston the granite columns from the old State House are being removed, and it is necessary to take them away in pieces; but those columns are not found to be in pieces, although they have been exposed to a wide range of temperature for nearly a hundred years. Imagine the entire State House as a block of granite. Would it have been split up by the frost or by changes in temperature? Scattered through the State of Maine are still larger blocks of granite, free from weather defects, although they have been exposed for intervals of time reckoned as ages in geology. It may be urged, however, that horizontal cleavage due to change of temperature in large work cannot be avoided. At what measured interval must such cleavage planes occur? Examine vertical walls in quarries, and natural escarpments of granite and sandstone, or other firm formations, and note the distance between the horizontal cleavage planes which Nature was obliged to adopt for her standard. How insignificant are all dams compared with the masses of sandstone in Western cañons, hundreds of feet in thickness and without a defect.

Is there any real trouble about placing in an Austin Dam, concrete of a quality to resist the uplift pressure, say, 20 or 30 lb. per sq. in.; or in many larger dams? Is there any real trouble about joining the work of one day to the work of the previous day or week, so that it shall be as strong as any other part? Such a dam, with the tensile strength of the material in excess of the uplift stresses by a proper safety factor, and designed without correction for uplift, would have no element of danger, if securely anchored, though the material were as porous as are many grades of sandstone.

If necessary, in construction, to avoid exposing the outer walls of a dam to low temperatures while the structure elsewhere is subjected to the high temperature due to the setting of the cement, a method less expensive than thickening the walls could be provided, and nearly uniform temperatures could be maintained as the work progressed.

Concrete and cyclopean masonry have been improved, and may be

Mr. Dunham. further improved, until they approach in quality a second or third-class sandstone, and later some of the firmer rocks.

The writer is aware that some authorities place the tensile strength of rather lean (1:2:5) concrete at 350 lb. per sq. in., and of sandstone as high as 500 lb. per sq. in., and other authorities recommend a zero factor for tensile strength in all masonry.

The sense of it all is this: Good construction is not subject to the defects which are common and often destructive enough in poor work. Everywhere the tendency should be to bring the quality up to the requirements of a good design, and not to fit a design to work of poor quality.

Mr. Smith. C. ELMORE SMITH, ASSOC. M. AM. SOC. C. E. (by letter).—The present-day development of large storage reservoirs, for domestic water supply, irrigation and power purposes, flood prevention, etc., has compelled the engineer to consider more and more carefully the masonry dam, and to evolve formulas which will take into account more and more fully the due importance of the supposed distribution of stresses in such structures; but, are we not still groping somewhat in the dark? It would seem to be high time that some large engineering body, educational institution, or branch of the National Government make an exhaustive study of the subject by testing to failure large models built under practical working conditions. This might well be done, and would at least get rid of all the more or less empirical formulas which are largely the result of development, along purely mathematical and theoretical lines, since the first dam was built.

In regard to hydrostatic pressure under the base of a dam, as Mr. Harrison says, this can only occur when the foundation rock is of a porous or stratified nature, "with well-defined horizontal seams;" and he has covered the ground in saying:

"Generally, it will be found cheaper to make large expenditures to provide a cut-off in the foundation * * * located at the heel of the dam."

When one considers the cost of the entire enterprise and the disastrous results of a failure, including loss of life and property, and the interrupted use of the reservoir, for whatever purpose constructed, too great a stress cannot be laid on the importance of first carrying the whole foundation to rock capable of supporting the great weight of the dam, and, further, of carrying the cut-off wall even to extreme depths to ensure the interception of all possible water-bearing strata or fissures. The question of the masonry being pervious to water, and thus creating hydrostatic pressure within the body of the dam itself, should not be discussed for a moment, as a masonry dam, when properly constructed, can and should be practically impervious.

In the design of masonry dams, the element of stress due to ice

pressure has interested engineers, and has been considered by them in different ways in making the plans for many of the structures now in existence. Mr. Smith.

It might be well to ask: are there any records of failures of dams due to ice pressure? Edward Wegmann, M. Am. Soc. C. E., mentions only one (that of the Minneapolis Mill Company, in 1899), and says that "there were special conditions in this instance which remove it from the ordinary case of ice pressure against a dam."

The Board of Experts, appointed to study the profile proposed by Mr. B. S. Church and the late Alphonse Fteley, Past-President, Am. Soc. C. E., for the Quaker Bridge Dam, adopted 43 000 lb. per lin. ft. as the extreme ice pressure. This and what they termed the effect of a possible transition wave caused them to add a thickness of about 9 ft. to the top section of the profile as proposed. The New Croton Dam—the Quaker Bridge project as finally located—was built, however, on substantially the first profile, without this added thickness. The profile of the extension of this dam was made 2.1 ft. thicker at an elevation of 100 ft. above the river bed, decreasing to zero at elevations about 40 ft. above and below this level, because J. Waldo Smith, M. Am. Soc. C. E., then Chief Engineer, believed the profile at this level to be deficient in strength. Did Mr. Smith consider ice pressure, in applying this added thickness?

In the design of the Cross River Dam, the ice pressure was taken at 24 000 lb. per lin. ft., and for the Croton Falls Dam, immediately thereafter, 30 000 lb. per lin. ft. was used. In the latter case, Alfred D. Flinn, M. Am. Soc. C. E., in charge of the design, explains this added 6 000 lb. by stating that "the configuration of the reservoir makes ice thrusts more probable."

These few cases in which ice pressure was considered have come under the writer's observation by his direct connection with the work.

If it is assumed that the probable extreme expansive pressure of ice is its crushing strength less a compression of from 6 to 30%, it would seem that there is need of reliable data and experiments in regard to this element of design, as the best data the writer can find (tests by the U. S. Engineer Corps in 1880) give the crushing strength of ice as varying from 100 to 1 000 lb. per sq. in., a difference too wide to permit of determining any very definite coefficient.

The design of dams has been an ever-recurring problem to the engineer, since the earliest times. From the earthen dams of ancient history to the first masonry structure, probably in Spain, about the Sixteenth Century, through the clumsy, faulty, and extravagant designs of the first Spanish dams and those of France early in the Nineteenth Century, which seem to have been built with very little if any conception of a theory of design, to the modern dams of the French, English, and Americans, the subject has been studied.

Mr. Smith. Through the researches of unknown early hydraulic engineers and of De Sazilly in 1853, Delocre, Rankine, Harlocher, Crugnola in 1882, and a host of others, the search for a rational theory of the design of masonry dams has been prosecuted; yet, when the plans for the great Quaker Bridge Dam were prepared under the direction of the late Isaac Newton, M. Am. Soc. C. E., assisted by the late E. S. Chesbrough, J. W. Adams, and J. B. Francis, Past-Presidents, Am. Soc. C. E., and the Aqueduct Commission ordered Mr. B. S. Church, its Chief Engineer, to make new and complete research on the problem of the design of a high masonry dam (Mr. Church assumed this important undertaking with the assistance of the late Alphonse Fteley, Past-President, Am. Soc. C. E., and J. P. Davis, M. Am. Soc. C. E.), very few new data were obtainable.

After protracted investigations, and much mathematical study by Mr. Wegmann, assisted by the late Ira A. Shaler, M. Am. Soc. C. E., a profile was finally evolved and presented to the Aqueduct Commissioners, accompanied by an exhaustive report, showing the result of all these investigations and the reasons for the profile proposed.*

Thus it is seen that, as late as 1892, engineers were still at odds over the question of the proper design of a masonry dam.

Then came the investigations of the Metropolitan Water Board of Boston, the studies for the proposed large dams for the irrigation projects of the United States Reclamation Service, those for the dams proposed on the Catskill Aqueduct System, and those for the dams in connection with the Panama Canal.

Are engineers now any nearer the ultimate solution of the rational theory of the design of structures of this class? Certain theoretical and mathematical deductions have been advanced; models of dams have been built, of wood, rubber, stone, and various other materials, all on a small scale, and these models have been tested in different ways; but these investigations assume conditions which are largely theoretical, namely, perfect elasticity of materials, uniform temperatures, uniform quality of materials and workmanship, and many ideals which are never obtained in practice.

Finally (though this matter is not strictly pertinent to the discussion of this paper), the writer wishes to urge upon the Profession his belief that, as masonry dams are generally monumental structures, they should be built as such. Only the best and most permanent architectural effects should be countenanced. No cheap "near stone" facing or mere veneering should be attempted or permitted, especially when dealing with a material like concrete, the durability of the face finish of which, to stand for centuries the rigors of this climate, may be questioned.

* Further historical matter submitted by Mr. Smith is omitted because the subject is covered fully in Mr. Wegmann's discussion.

Have not the engineers of Europe gone far ahead of those of America in this consideration; and is it not time for American engineers to add the element of beauty in architectural effects to their strictly utilitarian designs? Mr. Smith.

J. C. MEEM, M. AM. SOC. C. E. (by letter).—The writer has not followed the discussion of this paper closely, but has been interested in the paper itself, and in some of the discussion, particularly that by Mr. Godfrey, in which he makes a strong plea for the design of dams to include provision against uplift at full pressure over the whole area, and quotes in confirmation of his position, the following: Mr. Meem.

"Mr. J. B. Francis held that solid concrete deposited on bed rock would be lifted or floated, and to prove this, placed a pipe provided with a gauge, in the concrete of the dam and found that the gauge registered the full pressure."

The writer has for some time tried to have engineers distinguish between full pressure over the whole area, and full pressure on a percentage of the whole area. A dam cannot rest on rock (or ground either, for that matter) and be separated from it by even a minute layer or film of water over its whole area. That is, there must be areas of absolute contact distinguished from the porous areas through which on one side there is a flow of water causing pressure against a percentage of the area on the other.

The quantity of water which seeps into or sweats through a dam gives in some degree the relative porosity of the dam; and, assuming that another percentage of pores, probably small, does not find an outlet, it may be assumed that this latter percentage represents the area over which full pressure is exerted as uplift in the dam itself, and that this may vary from 1 to 10% of the whole, according to the material of which the dam is built. In the same way, considering the material on which it is built, the water through a percentage of the seams (or voids) does not find an outlet, and here also it may be assumed that full pressure is exerted. The percentage in this case may be assumed to vary (roughly) from 1 to 40% of the whole area. The sum of these percentages can never by any possibility be more than 50, and in practice may never reach more than 5 or 10. For instance, if a table with a polished surface is placed in a receptacle and on it there is placed a block with a polished surface in contact with that of the table, then, assuming that the block has a specific gravity slightly less than that of water, it will not float when the receptacle is filled with water, because there is no area to make it buoyant. If, then, holes, the aggregate area of which is a little more than sufficient to cause the block to be buoyant, be drilled through the table, the block will float. If again, holes be drilled through the block to correspond exactly with those in the table, again the block will not float; although, if one or two of these holes be plugged with

Mr. Meem. a gauge they will show full hydrostatic pressure. Exactly the same condition should obtain in a dam on rock or firm ground, except that the contact of the two polished surfaces is replaced by the contact between concrete and stone, or concrete and the soil, which is very intimate.

Every existing chamber which has no outlet (or any gauge placed at the foundation or in the material of the dam) will undoubtedly in time show full hydrostatic pressure. That is, it will be in effect the chamber of a hydraulic jack.

When concrete which has been deposited on rock bursts up (if it ever does) it will not do so until the full pressure, multiplied by what may be defined as the porous area, is greater than the weight of the concrete. The writer's attention has been called to a case in which a pump-house has a floor of concrete resting on ground in which the weight of the floor is not heavy enough to resist full pressure over the whole area, and yet the floor is there. He believes that many cases of floors bursting up will be found to be caused by the pressure being sufficiently in excess of the weight to offset the diminished area against which the pressure initially acts; still, any of these cases may not in themselves be conclusive as applied to masonry dams on rock. It may be of interest to note that the gauges in the Battery Tunnel always showed full hydrostatic pressure, and yet the tunnel, with a relative buoyancy in excess of its weight of more than 3 tons per ft., sank under any disturbance of the surrounding material during construction.

Finally, the writer wishes to emphasize the fact that he does not desire to take issue with those who would use in design large factors of safety against all possible contingencies, but does wish to make clear the fact that engineers should use their technical knowledge and experience to design as nearly correctly as possible, and then should provide against contingencies by using such factors of safety as judgment or experience may dictate.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

HOW TO BUILD A STONE JETTY ON A SAND BOTTOM IN THE OPEN SEA.

Discussion.*

By J. Francis Le Baron, M. Am. Soc. C. E.

J. Francis Le Baron, M. Am. Soc. C. E. (by letter).—This somewhat didactical paper gives in small compass some recognized facts and practical information in reference to jetty building in the open sea, but does not seem to present any facts not previously well known and tried by harbor engineers. As the writer cannot agree with some of the conclusions and methods, he will discuss them from his standpoint. Mr. Le Baron.

In the first place, the author's definition of a jetty is very circumscribed. More than a dozen types of construction are used in building jetties in the open sea, some being adaptable at one place and some at another. Probably Mr. Ripley intended his definition to apply only to the particular method of construction which he was using, or had in mind; but, if he advocates for all cases only the fixed plan which he describes, the writer must take issue with him at once, because, if there is any one thing that thirty years' experience in building sea works has taught, it is that no single type can be used for all places. What may be proper for one river mouth may be entirely unsuited for another.

The destructive forces in an "open sea" vary greatly, according to circumstances, the factors being the "fetch," tides, currents, prevailing winds, hurricanes, sea bottom, offshore depths, and sea worms. None of these conditions is the same in all places; therefore, good judgment is required in the selection of the most appropriate type for a given location, and this selection calls for professional knowledge of a high order, and ripe experience. The writer, believing that

*Continued from January, 1912, *Proceedings*.

Mr. Le Baron.

Mr. Ripley has both, cannot think that he advocates, for all outside work, a jetty of the type he describes, because the first duty of the engineer is to design works most appropriate for each particular case, and this word, "appropriate," includes strength, durability, effectiveness, and economy.

During the past thirty-two years, the writer (either as assistant, chief, or consulting engineer, or contractor) has been connected with jetty work, in open sea or lake, costing more than $8 500 000, and 98% of this has been built or is now building. The types have included rip-rap rock, log-mat and rock, brush mattress and rock, rock and mud-filled cribs, plank and pile jetty, and log and pile jetty; and, on some of the large works, three of these types have been combined in one jetty. On the Western coast, jetties more than 5 miles long, are now being built according to the designs of the writer, as consulting engineer. These are of composite type, because it is not necessary for the whole length to be as massive and strong as the outer end. Thus, by using a much lighter and cheaper construction near the shore, much money can be saved. The first 3 100 ft. from the shore is simply pile and single-plank bulkhead, to be reinforced by material dredged from the channel. This is followed by 3 800 ft. of double-plank bulkhead, 5 ft. wide from center to center longitudinally, cross-capped, and filled with brush fascines and broken stone. The remainder is built of log mats covered with rip-rap, and with large rock for some distance from the sea end.

For many years it was thought that loose rock drawn down on the floor of the ocean would be swallowed up in the sand, but this is not the case, except in a few locations, and it has long been known that such rock will not sink more than about 1 ft. in the sand. The reason for using log mats, instead of loose rip-rap, for a foundation, is the saving in cost. Log mats can be made and laid in the work for about half as much as it would cost to fill the same space with rip-rap; and, as there are no teredos, and the logs are always wet, they will be practically imperishable. It is estimated that the use of log mats, instead of a rip-rap foundation, will save more than $500 000 on this work, and, even if teredos were present, they would not attack the logs in the foundation course, as the superincumbent weight sinks these logs in the sea bottom and they are also covered with sand and broken shells by the currents and wave wash, under which conditions it is well known that these sea worms cannot work. In most places, also, this process is materially assisted by a thick growth of shell-fish of various kinds, by which the logs and rocks are sometimes completely covered.

The proportions of the jetty detailed by Mr. Ripley are too small for any exposed place. For outside work on the Atlantic and Pacific Coasts, the writer has always used a top width of 40 ft. and side

slopes of 2:1, and believes that, in many locations, 4:1 is better for the outside. It must be remembered that structures of this kind are built for all time, and are not like bridges or viaducts, many of which are destined to be torn down when the railroad for which they were erected adopts heavier locomotives or changes its location. Mr. Le Baron.

The sea ends of jetties are similar to breakwaters, and it is well known that the action of the sea, on most of these important structures, has reduced the outer slope between high and low water to an inclination varying from 3:1 down to 7:1. In 50 ft. of water the writer has used an apron 125 ft. wide, on each side, with a jetty base of 240 ft., making a total width of 490 ft., or about twice as great as Mr. Ripley recommends; and it was not too wide.

Jetties must be strong enough to withstand the great storms to which they will be exposed every few years, or they will be expensive failures. The author dismisses the question as to the effects of such storms in a naïve manner, as "problematical." In proportioning the width of the apron, he estimates that the damage from overfall is caused by the waves only. It has happened in the writer's experience, that where the jetty crossed the deep channel, a tidal overfall of 1 ft. has set up a whirlpool, or boiling action, and has scoured out potholes 50 ft. deep at the base of the jetty before the apron was laid.

Mr. Ripley's plan of laying the foundation and apron, or a large part of it, in advance of the building of any superstructure, is heartily endorsed by the writer, who has always insisted on this in his later works. The construction of the berm is not made clear in the paper, but, on the channel side, it is presumably made necessary by scour in the channel after the completion of the jetty. If log or brush mats are used in the apron (which is by far the best and safest plan), this berm is formed automatically, if the apron when first laid is of sufficient width. The scour, if any, must then necessarily take place on its outer edge. If it does not undermine the apron, it does no harm; if it does, the edge of the mat with its load of stone drops, accommodates itself to the slope, and effectively protects it. In practice, this is found to be what takes place when such mats, loaded with stone, are used as aprons, and it is one of their great advantages over loose rip-rap.

Mr. Ripley's plan of throwing down a loose foundation course of rip-rap and constructing the jetty thereon, from the sea toward the shore, instead of from the shore outward, is contrary to all precedent, and the writer considers it very dangerous. Possibly this might be done at some small river mouth, not much exposed, and where the tidal rise is small, as in the Gulf of Mexico or the Caribbean Sea, but such a method of procedure at the mouth of a river like the Columbia, on the Pacific Coast, or the St. John's, of Florida, appears to be quixotic in the extreme. At nearly all large river mouths or estuary

Mr. Le Baron. bars where there is considerable rise and fall of the tide, there is what is known as a "swash channel," which runs close to the shore and is generally a small shallow run formed by the flood tide; and this has to be crossed by the jetty.

On Cumberland Sound (Georgia and Florida) the foundation course of the north jetty was laid from shore nearly 4 miles seaward over the bar, all of it, except where it crossed the swash channel, being on a sand bank, awash, or only a fraction of a foot above low water. This foundation course consisted of a log mat with large brush securely bound on top, the whole being covered with 1 ft. of broken rock. This made a base 40 ft. wide and 3 ft. thick, with the brush tops projecting beyond the sides. At half and high tide it was exposed to the full sweep of the Atlantic. Owing to the lack of an appropriation by Congress, it was left in this condition for two years, during which time the sea washed off nearly all the rock and cut numerous gullies through it. Later, the same thing happened to the north jetty at St. John's River bar, which was of similar type and on a similar sand bank, but this bank was as much as 2 ft. above low water in one place, and was about 2 miles long. It was intended that the mats, when laid, should be lapped about 6 ft., but, owing to the heavy surf, this was at times impossible, and gaps were left between the two mats. Small mats were used in filling the larger gaps, and rip-rap was deposited in the smaller ones. In many places, especially in the swash channel, these gaps eventually were gullied out to a depth of 10 or 12 ft. At those places the stone was washed out or sunk by the currents cutting away the sand, and mats had to be sunk in them. Judging from these experiences the writer is strongly of the opinion that, if rip-rap had simply been thrown down, and no mats had been used, the foundation would have been destroyed.

Mr. Ripley's idea of building the foundation in heavy seas (by first throwing down small rip-rap on the sand bottom, to be followed later by larger stone) might be practicable in some small lake, but those who have witnessed the tremendous power of the waves on outer bars on the Atlantic and Pacific Coasts would be loath to try it. As it is known that rocks weighing scores of tons are taken up by the waves from low water and carried nearly to high water, up a steeply inclined beach, it would seem preposterous to expect a wall of small, loose rip-rap, 2 or 3 ft. high, to stand. It would be preferable to lay the larger stones first.

The north St. John's jetty was afterward built up at the outer end to about half tide, with the result that an excessive scour developed in the swash channel and at the beach, which was eroded for several hundred yards and had to be at once protected by mats and rip-rap at large expense. This would not have been necessary had the jetty been built out from the shore, because, in that case it would have

Mr. Le Baron.

been a groyne, and it is, and always has been, the practice everywhere to build groynes from the shore out; otherwise they would not hold the sand and build up the beach.

The south St. John's jetty was built from the shore out, the foundation course being kept well in advance. The re-entrant angle of the beach has been filled solid for a mile out from shore, where the water was formerly 40 ft. deep.

Many years ago, on the Fraser River, in British Columbia, attempts were made to improve the navigation near the mouth by building detached sections of jetty, or training walls, in several places. When the writer examined the river, a few years ago, and made plans for its permanent improvement (now being carried out), these constructions, with a single exception, had disappeared, having been undermined and destroyed because they were disconnected and unsupported, like a small detachment of an army in an enemy's country.

The writer is strongly opposed to such methods, and would not consider the small rip-rap foundation, described by Mr. Ripley, a safe protection at any river mouth on the Atlantic or Pacific, however well it might answer in the Gulf of Mexico or some of the lakes. This, however, is entirely a matter of judgment and experience, for what might be good for one locality might be fatal for another. In sheltered places, where the tidal range is slight, there would not be much danger in commencing the construction of the jetty at the outer end, provided a solid and adequate foundation had been laid first and precaution had been taken to protect the shore end from erosion; and provided, also, that anything was to be gained by it, but the writer's experience shows that there is not.

The value of the isolated section of jetty as a protection to the vessels while working, as claimed by Mr. Ripley, is largely overestimated, as a little reflection will show. According to this plan, the jetty, at high water, will be only 26 or 27 ft. wide at the water surface, and 3 ft. high. If there is any troublesome surf, it will roll over this slight obstruction. At low water the protection would be a trifle better, but, as the scows and tugs depositing stone must be near the axis of the work, it is only when the wind and waves coincide with this axis, in one direction, that it will afford any lee. In other words, the wind blowing across the jetty line would not make any lee for the vessels, though they might work on the other jetty if the wind was right; but this protection would also be afforded if the jetties were being built from the shore outward. When the wind is blowing from the unbuilt part toward the part already built, the jetty will afford no protection. On the contrary, it will be a rocky lee shore, very dangerous to approach. There might not be one day in a month when the wind would blow in the right direction to afford any practical protection.

Mr. Le Baron. Mr. Ripley's theory, that, by commencing construction at the outer end and working shoreward, the advance of the bar will be prevented entirely and the jetty channel will be deepened more rapidly, is untenable; at least, the writer's experience indicates that it would be very dangerous procedure.

For improvement purposes, all rivers are classed as sediment- or non-sediment-bearing streams. The Mississippi and the Fraser may be taken as types of the former, and the St. John's, of Florida, as of the latter class. In some places there is a strong littoral current in the ocean in front of a river mouth; in others there is no trace of such a current, or it obtains for only a part of the year. In some places the prevailing winds blow dead on shore; in others they are along shore. In the latter case they produce a wave race along the beach which is fully as effective as the regular currents. All these forces must be taken into account in the study of bar advance.

Now, the author supposes that he has commenced the construction of two parallel jetties over the bar, and states that the material between these jetties will commence eroding and working backward, will produce a deep channel, and "the material thus eroded from the channelway will be carried beyond the outer ends of the jetties, where it will be either swept to one side by the littoral current or deposited in the deep water farther out." He offers no confirmation of this statement, and makes no reference to examples of works constructed in which these movements occurred. On the contrary, the probabilities are that each section of isolated jetty would form the nucleus of a sand island, because no power would be brought into action to direct the river channel between such sections, and it would be just as apt to break out a new channel in an entirely different location.

Channels through river bars are constantly changing. In all bars studied by the writer the channel swings in regular cycles, of from 25 to 100 years' duration, from one side of the entrance to the other, working gradually, for example, down to the south side of the entrance close to the shore, then suddenly breaking out away up on the north side, and slowly working back. The jetty may be planned to run out through the center of the entrance, or to follow the existing channel, which at the time may be close to the south shore. The channel may, and most likely will, jump to a different part of the entrance after some hard storm, and the isolated sections of unfinished jetty will be left standing alone in the water or sand. The foundation line of rip-rap would have no effect in preventing or modifying this change, for the writer has seen the old channel abandoned and a new one formed across the foundation course of a jetty which he built at Fernandina, Fla., and it deepened so much that it was used by large vessels.

Suppose the jetty channel had been laid out to follow as nearly

as possible the existing ship channel, that construction had been commenced at the outer end, and that the channel had shifted as it did at Fernandina. The whole length of the old channel which the jetties had been planned to follow would then fill up, because there would be no jetty to direct the currents, and therefore it would be necessary to build in from sea to shore over a continuous sand bank, covered with breakers at high tide, and impossible for tugs and lighters at low tide without the advantage of a deep channel from which to work; in fact, it would probably become necessary to clear the jetty channel by dredging. Mr. Le Baron.

Again, suppose the jetties to have been planned to run straight out to sea over the sand banks—as is often desirable—regardless of the existing deep channel. In this case the same objections would apply, but in greater degree. The writer would like Mr. Ripley to state how it would be practical or even possible to proceed on his plan on a rough and stormy coast.

Under the foregoing conditions, suppose that the entrance, measured on the outer edge of the bar, is 2 miles wide; that each jetty is to be 3 miles long—an average condition—to reach deep water; that work has been commenced at the outer ends, and ½ mile has been completed. This will represent only about 16% of the total length, and will be a very small spot in the waste of waters. It is hardly conceivable that, under such conditions, any scour would take place in the channel until the jetties had been completed to or near the shore. In the meantime, cross-currents will be set up in all directions, the swash channel will surely be deepened, and there will be grave danger of cutting away the beaches, if they are of sand, and low, as is generally the case. Thus the additional dredging and revetting will be almost certain to entail heavy expense.

The filling of the jetty channel can be most certainly predicted, as many bars are formed by the transportation of sand detritus along the coast by littoral currents or surf-race, instead of by river deposition alone. By microscopical examination, Count Pourtales, of the United States Coast and Geodetic Survey, found that the material forming the outer shoals and bars at Boston Harbor was composed of detritus washed and transported from near-by headlands. In all non-sediment-bearing streams this is necessarily the case. In discussing the question of bar advance, one must discriminate sharply between sediment- and non-sediment-bearing streams. In places where there is no littoral current, or a pronounced and continuous surf-race, bar advance will always follow, sooner or later, the construction of jetties at the mouths of sediment-bearing streams, unless the bottom drops rapidly, as it does at the Fraser River.

Mr. Ripley makes no distinction between these radically different types of streams, and appears to ignore the work of the surf-race and

Mr. Le Baron.

littoral currents in their endeavor to perfect the littoral cordon; apparently, he considers the river bars as formed entirely of river sediment and material washed up from the floor of the ocean in front of the mouth, for he speaks of the position of the bar being determined by the equilibrium of the ocean and river forces, one force (the river) tending to push it seaward, while the other tends to push it back. In reality, these two forces are disturbed by the littoral current (if any) or the surf-race eroding the adjoining beaches and bringing along shore material to assist in filling the river mouth and building out the bar. It is by all these forces that bars are formed, some predominating in one place, and others in another.

The author's claim that, if jetty construction is commenced at the sea end, the bar advance will be minimized, or wholly prevented, appears to the writer to be "not proven," not to say fallacious.

In this discussion, the writer has shown the possibility, or, more correctly, the extreme probability, of the jetty channel being filled with sand in some places, if Mr. Ripley's methods are carried out, and therefore that the quantity of material to be moved will be greatly increased. Mr. Ripley says:

"The material thus eroded from the channelway will be carried beyond the outer ends of the jetties, where it will be either swept to one side by the littoral current or deposited in the deep water farther out."

This is what takes place with any system of parallel or converging jetties, properly spaced, and with sufficient current in the jetty channel to move the sand. In no event will there be any erosion unless the outgoing current has sufficient velocity to move the material composing the bottom. In order to produce this velocity, there must be a head of water.

In the plan advocated by Mr. Ripley, all head is eliminated, because the jetties are at the foot of the slope, in the dead level of the "open sea," and all the slope is shoreward. With jetties built out from shore, on the other hand, advantage is taken of the natural slope of the outlet, which is further augmented by the convergence necessarily given to the jetties by their shore connections; this has the effect of piling up the water in the upper end of the contraction, and materially increasing the head, and therefore the scouring power. In the author's plan this is all lost until the whole system is completed, so that no advantage can be taken of a deep channel for working.

If there is any littoral current, the eroded material will be swept aside just the same, no matter whether the work is begun on the bar or at the shore. The important thing is to induce sufficient erosion to move the material out of the channelway. If there is no littoral current, this material will be deposited, during construction, on the ocean floor in front of the jetties, no matter which method is adopted;

and, if the ocean floor is elevated, and the water shallow, the bar will necessarily be advanced in either case. Mr. Le Baron.

The claim that this result will not follow if the author's method is adopted, is totally disproved by the writer's experience. The north jetty at St. John's River bar was laid out by him, and partly built under his superintendence. The foundation course was first built out for about 2 miles. Then the outer end of the jetty was raised to about half tide, where it remained for several years; it was then raised to mean high water, and part of the outer end of the south jetty was also raised above high water before the inner end. According to Mr. Ripley's theory, it would be expected that the bar advance would be retarded, but, as a matter of fact, the 30-ft. curve has moved out nearly a mile in front of the jetties.

A hearting of small stone and the protection of the slopes and top with large blocks have always been good practice. A hearting of oyster shells has been used, and, when plentiful and convenient, does very well. The writer quite agrees with Mr. Ripley in reference to the kind of rock which is most desirable; he also believes in wave washing as a factor in consolidating the stone; and in the importance of making the jetty as nearly water-tight as possible.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

SPECIFICATIONS FOR THE DESIGN OF BRIDGES AND SUBWAYS.
Discussion.*

By Messrs. S. W. Bowen, Victor H. Cochrane, Albert I. Frye, F. W. Gardiner, and Almon H. Fuller.

S. W. Bowen, Assoc. M. Am. Soc. C. E. (by letter).—This very complete set of specifications is of much interest to the Profession in general, and especially to those engaged in designing and constructing bridges. Specifications such as these, which apply without modification to bridges of any span, are simple of application and a great help to the designer. Mr. Bowen.

The writer has long felt that the method of proportioning bridge members by using a constant unit stress and an allowance for impact is the logical one, and, for some time, has been collecting all available data on impact tests. On Plate XII the impact tests made by Mr. Greiner, and shown on Mr. Seaman's diagram, Fig. 7, have been plotted; and to these have been added the tests made by the late S. W. Robinson, M. Am. Soc. C. E.,† and by F. E. Turneaure, Assoc. M. Am. Soc. C. E.,‡ together with those made by the American Railway Engineering and Maintenance of Way Association.§

The tests made by Professors Robinson and Turneaure, and some of those made by Mr. Greiner, were taken from a diagram published by Henry S. Prichard, M. Am. Soc. C. E.,|| in connection with an article entitled "The Proportioning of Steel Railway Bridge Members."

* This discussion (of the paper by Henry B. Seaman, M. Am. Soc. C. E., published in *Proceedings* for December, 1911, but not presented at any meeting) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *Transactions*, Am. Soc. C. E., Vol. XVI, p. 42.

‡ *Transactions*, Am. Soc. C. E., Vol. XLI, p. 410.

§ Bulletin No. 125, July, 1910.

|| *Engineering News*, September 19th, 1907.

Mr. Bowen.

In all, the results of one hundred and thirty-eight tests are shown on Plate XII. These are mainly on comparatively short spans, the longest recorded being that of the 440-ft., double-track bridge on the Burlington Road over the Missouri River at Bellefontaine, Mo. Tests on longer spans and on very short ones are needed to cover the field fully, and it is to be hoped that the Maintenance of Way Association will present the results of such tests at an early date.

On Plate XII the writer has plotted the impact formula, $S = \dfrac{100}{1 + \dfrac{L^2}{20\,000}}$, given by the American Railway Engineering and Maintenance of Way Association, and Mr. Seaman's formula, $S = 125 - \frac{1}{8}\sqrt{2\,000\,L - L^2}$. The latter seems to fit the results of the extreme tests better than the former; especially for loaded lengths of 150 ft. and greater. The single point falling seriously outside of both curves is the one for $L = 80$ ft. and $S = 100\%$ (this test may be unreliable).

It would seem safe and reasonable to make the impact allowance for highway structures not more than 50% of that for railway structures, with a further material reduction of the impact allowance on the highway portion of the live load in the case of combined highway and railway bridges.

The unit tensile stress of 20 000 lb. per sq. in. for medium steel under static load, seems high, in view of the fact that secondary stresses, natural increase in the live load, and deterioration will add very considerably to the axial stress, and, in some cases, may bring the total up close to the elastic limit of the metal. In the writer's opinion, 16 000 lb. per sq. in. in tension, and 16 000 lb., properly reduced for compression, with a maximum in compression of 14 000 lb. per sq. in., comes more nearly within the safe carrying capacity of this material.

In the specifications for reinforced concrete, the requirement that beams and slabs shall be calculated as simply supported, seems to be rather severe. This clause was probably framed to comply with the New York Building Laws, which, until very recently, were extremely conservative in this respect. Most building laws allow such parts to be calculated for a bending moment at the center of the span of from $\frac{WL}{12}$ to $\frac{WL}{10}$; steel being provided, of course, to take the negative bending moments over the supports. Where the foundation is good, this method of computation is warranted by the monolithic character of the construction.

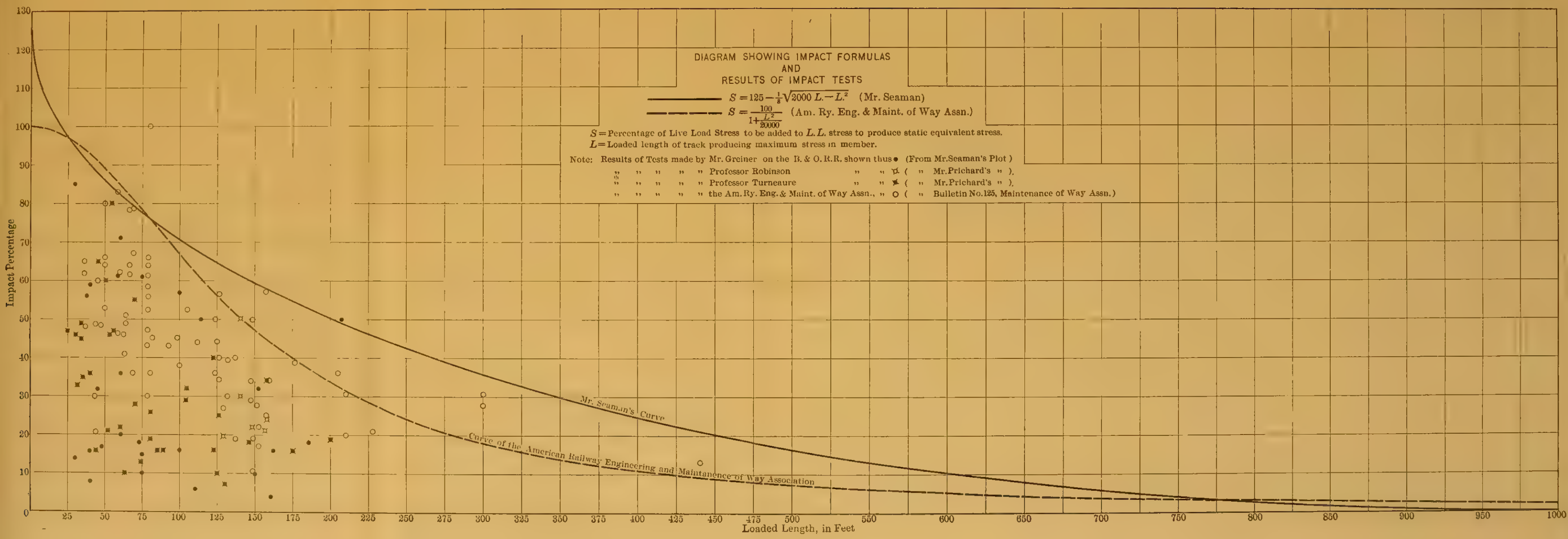


DIAGRAM SHOWING IMPACT FORMULAS
AND
RESULTS OF IMPACT TESTS
$S = 125 - \frac{1}{8}\sqrt{2000\,L. - L.^2}$ (Mr. Seaman)
$S = \frac{100}{1 + \frac{L^2}{20000}}$ (Am. Ry. Eng. & Maint. of Way Assn.)
S = Percentage of Live Load Stress to be added to $L.L.$ stress to produce static equivalent stress.
L = Loaded length of track producing maximum stress in member.
Note: Results of Tests made by Mr. Greiner on the B. & O. R.R. shown thus ● (From Mr. Seaman's Plot)
" " " " " Professor Robinson " " (" Mr. Prichard's ").
" " " " " Professor Turneaure " " (" Mr. Prichard's ").
" " " " " the Am. Ry. Eng. & Maint. of Way Assn., " ○ (" Bulletin No. 125, Maintenance of Way Assn.)
Mr. Seaman's Curve
Curve of the American Railway Engineering and Maintanence of Way Association
Impact Percentage
Loaded Length, in Feet
0
10
20
30
40
50
60
70
80
90
100
110
120
130
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
550
600
650
700
750
800
850
900
950
1000

Mr. Cochrane.

VICTOR H. COCHRANE, M. AM. SOC. C. E. (by letter).—This paper is timely because of the fact that many bridge designers are realizing the desirability of a more or less thoroughgoing revision of the specifications in general use.

The writer has recently been engaged in revising the specifications used by his firm for the design and construction of bridges, and has reached certain conclusions somewhat at variance with those of Mr. Seaman.

It is gratifying to note that the old practice of reducing the working stresses to provide for the live-load effects is being abandoned. It certainly leads to greater clearness and consistency to reduce all loads to the basis of an equivalent dead load and then to use the same working stresses throughout. The saving in labor effected by this method is not inconsiderable, as the author remarks.

The most rational and satisfactory method of design, therefore, would appear to be to divide all the uncertainties into two classes, proceeding as follows:

1st. Increase the live-load strains by an increment which will take care of the uncertainties due to the application of the live load, that is, due to the fact that the load is moving instead of stationary.

2d. Use working stresses selected so as to provide for the uncertainties in regard to the behavior of the materials as used in the structure. Thus the working stresses should be chosen so as to take into account the effect of secondary stresses of various kinds, the variation in strength of compression members due to variation in the ratio $\frac{l}{r}$, and the like.

Mr. Seaman's static equivalent formula is intended to cover all the uncertainties of the first class. He seems to use the term "impact" in the sense of the effect due to the suddenness of application of the live load. The writer understands, however, that the term "impact" has long been used to mean precisely what the author calls "static equivalent." It would seem, however, that Mr. Seaman's term is a decided improvement.

The author does not seem to have taken into account the impact tests made under the direction of the American Railway Engineering and Maintenance of Way Association.*

In Fig. 19 are plotted some results of the tests by Mr. Greiner and those by the American Railway Engineering and Maintenance of Way Association. Only the maximum values are given, regardless of the type of structure or the character of the member tested. It

* The results are published in Bulletin No. 125 of that Association.

Mr. Cochrane. should be remembered that these tests are all for railway loads. Fig. 19 also shows, for the sake of comparison, various impact or static equivalent formulas.

As brought out in Bulletin No. 125, just referred to, the chief cause of impact in long spans is the unbalanced condition of the locomotive drivers; and the maximum impacts occur when the time of rotation of these drivers is the same as the time of vibration of the span. In the case of short spans, such as plate-girder spans, the time of rotation of the drivers, even at the highest speeds, is greater than the vibration period of the span. In this case the impact values increase with the speed. Hence, there seems reason to believe that, from theoretical considerations, the impact may be less for very short plate-girder spans than for those somewhat longer. This view is borne out to some extent by the results of the tests. As will be seen in Fig. 19, the highest value of all (about 133%) occurred in the case of the 60-ft. span. Therefore, if the above statement be true, it may be found that some such curve as that shown by the line, C, for which the equation (using the author's notation) is $S = \dfrac{80}{100 + 1.1\,L - 12\sqrt{L}}$, represents the maximum impacts which might be obtained. The values increase from 100% for the 5-ft. span to 119% for the 30-ft. span, and then decrease rapidly.

The writer believes, however, that this formula and Mr. Seaman's give higher values than necessary for the shorter spans. Values exceeding 100% are very exceptional, and it is thought that a maximum of 100% is quite sufficient.

The formula in most general use, $S = \dfrac{300}{L + 300}$, known as the American Bridge Company formula, is shown by the curve, B. Considering the lack of knowledge at the time it was put into use, it has served its purpose admirably. It appears, however, that it gives values somewhat too small for spans of 100 ft. and less, and much too large for spans of more than 200 or 300 ft. In the case of the 600-ft. span, the impact increment given by this formula is $33\frac{1}{3}$%; while only 10% is given by the author's formula. Conservative designers will, perhaps, hesitate to make such a radical change in present practice. The writer has adopted the formula, $S = \dfrac{800}{800 + L + \left(\dfrac{L}{10}\right)^2}$, plotted as curve D. It gives somewhat higher values than the author's formula for all spans exceeding about 40 ft.

The tests of the American Railway Engineering and Maintenance of Way Association seem to have established the fact that the ratio of dead load to live load has but little influence on the value of the

Mr. Cochrane.

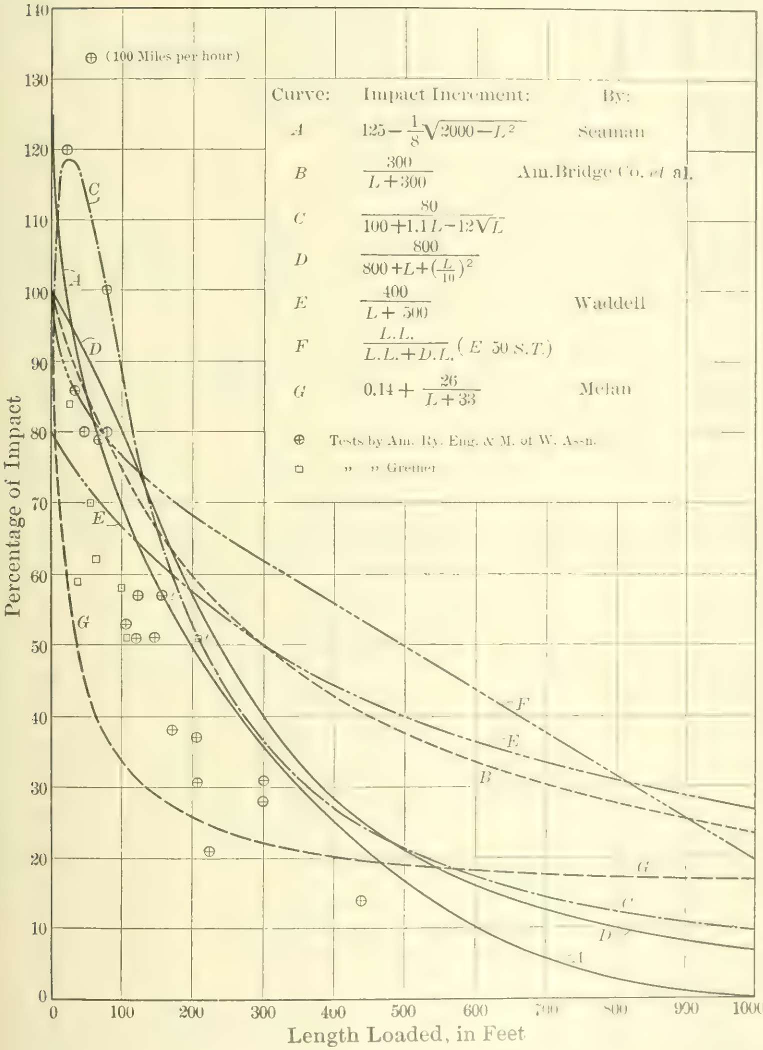


FIG. 19.

Mr. Cochrane.

impact increment. Consequently, the formula in general use, $S = \frac{L.\ L.}{L.\ L. + D.\ L.}$ (in which $L.\ L.$ denotes the live load and $D.\ L.$ denotes the dead load), cannot be justified. The curve, F, gives approximate values of this ratio for single-track railway spans designed for Cooper's E-50 loading. It will be seen that it gives values very much too high for long spans. The curve, E, is plotted from Waddell's formula, $S = \frac{400}{L + 500}$. The curve, G, gives the values determined by Melan's formula, $S = 0.14 + \frac{26}{L + 33}$. This formula is said to have been derived from theoretical considerations, but it is not at all in accord with experimental results. Some specifications in common use provide for impact by making the working stresses for dead load twice those for live load. This method is illogical, and leads to inconsistent results. Moreover, it leads to unnecessary difficulties in detailing connections, for the reason that these must be designed, not for computed, but for hypothetical stresses which will develop the full strength of the members.

Mr. Seaman has derived his impact formula from the results of tests on railway spans. It would seem to be an unwarranted procedure to apply this formula to highway loads. It is probable that the static equivalent for highway loads is only a small proportion of that for railway loads. Indeed, some specifications treat moving loads for highway bridges as static loads. The writer thinks it would be better to use a different formula for highway loads, or, in view of the present lack of knowledge concerning highway impacts, to use a certain proportion of the values for railway loads, say 33⅓ per cent.

Whatever impact increment is allowed must be considered in connection with the working stresses, in order to form a judgment as to the safety of the resulting design. Comparing the working stresses of the author's specifications with those in common use, it will be seen that the value for tension in medium-steel members is 25% higher than that in common use (16 000 lb. per sq. in.). Taking this fact in connection with the great reduction in the impact allowance for long spans, it will be seen that the author's specifications constitute a radical departure from current practice.

Relative to this matter, it may be of interest to calculate the bottom chord sections at the center of a 300-ft., single-track, railway span, by the author's specifications and by those of the American Railway Engineering and Maintenance of Way Association, and compare the results. The approximate equivalent live load for E-50 loading will be used for convenience, and the truss depth will be taken as 55 ft.

Mr. Cochrane.

	By the author's specifications.	By the specifications of the Am. Ry. Eng. & M. of W. Ass'n.
Equivalent live load per linear foot per truss........	2 720	2 720
Impact increment..35.7% =	970	50% = 1 360
Dead load per truss........	1 350	1 800
Total load, W.......	5 040	5 880
Chord stress $= \dfrac{W \times (300)^2}{8 \times 55}$..	1 030 000	1 205 000
Section required...........	51.5 sq. in.	75.3 sq. in.

It will be seen from this calculation that in this case the Maintenance of Way specifications require sections about 46% greater than those obtained under the author's specifications. Hence it must be concluded:

1st. That the author's working stresses are much too high; or,

2d. That most specifications in use lead to wasteful designs.

Inspection of the values given by Mr. Seaman's static equivalent formula will show that they are quite small for what might be termed long spans. Then, granting (for the sake of argument) that short spans as designed under the specifications in general use are not heavier than it is advisable for safety to make them, it follows either that the author's working stresses are too high for long spans, or that higher working stresses may be used for long spans than for short ones. It may be argued that the latter alternative is justifiable on the ground that short spans are more likely to be overloaded than long ones. It would seem to be more logical, however, to provide for this tendency by specifying adequate live loads. There has been a well-defined disposition to use comparatively higher working stresses for long spans than for short ones. Probably this tendency has been due in some instances to the feeling that the specified live loads were excessive, but this statement could hardly be made in regard to the Quebec Bridge. The cantilever bridge at Beaver, Pa., recently completed, may be cited as an instance of a long-span bridge designed for heavy live loads and for working stresses substantially the same as those ordinarily used for short-span bridges.

Aside from the question whether the author's working stresses are, on the whole, too high, it is proper to inquire whether they are consistent among themselves.

A bearing value on pins of 30 000 lb. per sq. in. is very high. Relative to this matter, the paper by Mr. James E. Howard, "Some Tests of Large Steel Columns,"* furnishes valuable data, as was

* *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 429.

Mr. Cochrane. brought out clearly in the discussion by A. W. Carpenter and Charles Worthington, Members, Am. Soc. C. E. Long before the specified value of 30 000 lb. per sq. in. is reached the pin-plates will be permanently distorted at the pin-hole. For a column having the ratio, $\frac{l}{r} = 100$, the author's specifications would permit a unit bearing value on pins equal to nearly three and one-half times the working stress in the body of the member. Contrast this statement with the remark by Mr. Worthington, in his discussion of Mr. Howard's paper, that those tests "indicate that the working pressure on pins should not exceed the working compressive stress in the body of the member."

The consulting engineer, working under his own specifications, has the advantage that he does not have to consider the requirements thereof as fixed and immutable laws. He can modify the working stresses to suit the occasion. For example, in the case of a bridge having subdivided panels and carrying the floor loads directly on the bottom chords in bending, it would be proper, in view of the high secondary stresses in the chord due to the elongation of the hangers, to use low working stresses in the latter, so as to make the distortion small. It may be advisable to make some general distinctions in the specifications, such as to allow higher working stresses in stocky integral sections than in flimsy laced sections having the same $\frac{l}{r}$, and to require lower working stresses in the floor-beam hangers than in main members.

The specifications provide for braked train thrust as follows:

"Provision shall be made for the sudden starting or stopping of a train 500 ft. in length, estimating the coefficient of sliding friction at 10 per cent."

This value is too small for short railway spans. The traction coefficient should decrease with the length loaded. The writer uses the following rules:

For lengths up to 80 ft. . . . . $T = 0.20$

For lengths of more than 80 ft. $T = \dfrac{20 + \dfrac{L}{20}}{40 + L}$

in which T = the coefficient of thrust,

and L = the length loaded.

As a matter of fact, there is, generally speaking, no such thing as the sliding of a train on the rails, because the brakes in use are not powerful enough to lock the wheels.

The allowable pressure on 1:2:4 concrete is given as 60 k. per sq. ft., or 416 lb. per sq. in. A value of 700 lb. per sq. in. would be more in keeping with the other working stresses.

In view of the high working stresses adopted, one might expect to find elaborate requirements for the purpose of insuring proper detailing, especially in the case of heavy compression members. In this respect the specifications are disappointing. Mr. Cochrane.

The provision that no allowance is to be made for spliced webs in calculating girder flanges is commendable, as is the requirement that the splices of abutting compression members must transmit 50% of the stress.

ALBERT I. FRYE, M. AM. SOC. C. E. (by letter).—There are two points in this timely and valuable paper which the writer will discuss, namely: (1) the weight per cubic foot of materials; and (2) the formula for reducing applied loads to their approximate static equivalents. Mr. Frye.

The weight of steel should be given as 489.6 lb. per cu. ft. (2% heavier than iron, at 480 lb. per cu. ft.). The weights of earth, timber, and masonry, should be tabulated more in detail, with varying values for the different classes.

The author gives the following formula for deriving the static equivalent of applied loads:

$$S = 125 - \frac{1}{8} \sqrt{2\,000\,L - L^2}.$$

Where,

$S =$ Increase, in percentage;

and $L =$ Length, in feet, of applied loading which produces maximum strain in the member.

The writer proposes the following, because it is much simpler, and, in his opinion, gives values of S more nearly correct for the shorter lengths of loading:

$$S = \frac{25\,000 - 25\,L}{L + 200}.$$

For comparison, the values of S derived from these two formulas are given in Table 3.

TABLE 3.—COMPARATIVE VALUES OF S BY TWO FORMULAS.

L.	S. (Frye.)	S. (Seaman.)	L.	S. (Frye.)	S. (Seaman.)	L.	S. (Frye.)	S. (Seaman.)
0	*125.0	*125.0	90	78.5	73.2	300	35.0	35.7
10	117.9	107.4	100	75.0	70.5	350	29.5	30.0
20	111.4	100.1	120	68.7	65.6	400	*25.0	*25.0
30	105.4	94.6	140	63.2	61.2	500	17.9	16.8
40	100.0	90.0	150	60.7	59.2	600	12.5	10.4
50	95.0	86.0	160	58.3	57.2	700	8.3	5.8
60	90.4	82.4	180	53.9	53.5	800	5.0	2.5
70	86.1	79.1	200	*50.0	*50.0	900	2.3	0.6
80	82.1	76.0	250	41.7	42.3	1 000	*0.0	*0.0

* The two curves intersect at the four points, $L = 0$, 200, 400, and 1 000.

Mr. Frye. From Table 3 it will be noted that the increase in percentage, or "impact," is 100 for a 40-ft. length of loading, which is about the usual length (two panels) for maximum floor-beam reactions, and corresponds to what the writer considers good practice.

This is the reason for making the values of S, for short lengths of loading, greater than those given by the author's formula. The value, $25 L$, in the numerator of the second term of the formula can be obtained mentally, of course, by multiplying L by 100 and dividing by 4. Formulas of this character, necessarily empirical, must be in the simplest form possible if they are expected to come into general use.

Mr. Gardiner. F. W. GARDINER, M. AM. SOC. C. E. (by letter).—In Mr. Seaman's specifications the following statement is found:*

"Provision shall be made for the sudden starting or stopping of a train 500 ft. in length, estimating the coefficient of sliding friction at 10 per cent."

The force due to the starting or stopping of a train depends on the rate of acceleration or retardation. For trains of motor cars of the latest subway or suburban type, the motor equipment gives an acceleration having a maximum value of about $1\frac{1}{2}$ miles per hour per sec., and this rate is nearly uniform during the period of acceleration. The effect of this rate is a longitudinal force on the track of $91.3 \times 1\frac{1}{2} = 136.9$ lb. per ton of train weight, or 6.8 per cent. The latest type of braking equipment developed for use on ten-car trains of the Interborough Rapid Transit Company of New York retards the train for service stops at a rate having a maximum value of about $2\frac{1}{2}$ miles per hour per sec., corresponding to a longitudinal force on the track of $91.3 \times 2\frac{1}{2} = 229.2$ lb. per ton of train weight, or 11.4 per cent. This braking equipment retards the train, for emergency application, at an average rate of about $2\frac{1}{2}$ miles per hour per sec., but the rate is not uniform, and at the instant of stopping suddenly rises to about 5 miles per hour per sec. For emergency application of the brake at the instant of stopping, the longitudinal force on the track, therefore, is $91.3 \times 5 = 456.5$ lb. per ton of train weight, or 22.8 per cent. Emergency application occurs frequently, especially on trains equipped with automatic trips, and structures over which equipment of this type is operated will frequently have to resist a longitudinal force of 23% of the weight of one train.

Mr. Fuller. ALMON H. FULLER, M. AM. SOC. C. E. (by letter).—The fact that the author has departed from the usual custom of allowing a higher unit stress for a combination of wind stresses with dead and live loads, than for those from dead and live loads alone, emphasizes the uncertainty which frequently exists in determining the proper unit

* *Proceedings*, Am. Soc. C. E., December, 1911, p. 1275.

stress for combinations of compression and bending such as occur occasionally, especially in the end posts of an ordinary bridge. Mr. Fuller.

In light structures, it is not at all unusual that the actual unit stresses in the end post, due to transverse bending from the wind load and from eccentricity, exceed in magnitude those due to direct column action, while the allowable compressive stresses, reduced by the column formula, are only about one-half of those allowed for bending.

Although stresses from portal action are still occasionally neglected, under the assumption that the wind "shins down the post," the usual practice, as far as the writer is aware, is to base unit stresses for combined stresses in the end post on those indicated by the column formula. This practice, of course, is "on the safe side," but the possibility that it imposes unnecessary severity in many instances led the writer, about a year ago, to begin, in a modest manner, some combined compression and bending tests.

The only results available thus far are those from some small timber specimens, 1½ by 1½ in. by 2 ft., tested as thesis work by two seniors (Messrs. G. R. Edwards and C. A. Irle) at the University of Washington. These results indicate that, under the conditions under investigation, the actual stress at the elastic limit, and also at rupture, varies directly with the transverse load, from the values obtained in direct compression to those obtained in pure bending.

The writer realizes fully that these forty odd tests on small timber specimens cannot be used as a basis for writing a specification for the design of large steel members, yet he feels the need for something more specific than the existing specifications, and mentions the work already completed with the hope that it may possibly bring out further discussion on the subject.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM BILLINGS CLAPP, M. Am. Soc. C. E.*

DIED DECEMBER 27TH, 1911.

William Billings Clapp was born in Conway, Mass., on April 11th, 1861. In his early boyhood his parents migrated to Southern California and were among the first group of families in the "Indiana Colony" that settled on Pasadena lands. The story of this colony forms in large measure the history of modern Pasadena.

Mr. Clapp's engineering education was largely acquired in the field, and the field of California was at that time, as it is to-day, unusually rich in opportunities for practical engineering instruction. In 1882 he was Assistant in public land subdivision surveys in Northern California. From 1883 to 1886 he was Assistant Engineer in charge of the construction of the Los Angeles and San Gabriel Valley Railroad. Subsequently he was Assistant Engineer for the Los Angeles and Salt Lake Railway Company, and in 1889 engaged in private engineering work at Seattle, Wash.

Returning to California in 1891, he became Engineer and Roadmaster for the San Gabriel Valley Rapid Transit Company. In 1893 he engaged in general practice in Pasadena, Cal., and in 1894, and for six years subsequent thereto, he was City Engineer in Pasadena, during which period that municipality began its transition from a rural settlement to the modern city of to-day.

In the course of his service, Mr. Clapp was identified with the radical improvements and changes that necessarily precede and are fundamental to modern city development. From 1901 to 1903 he again engaged in private practice, giving a part of his time to the water resources investigations of the Geological Survey. On May 5th, 1903, he was appointed an Assistant Engineer in the Geological Survey, and from that date until his final illness he was identified with the hydraulic investigations of that bureau in California. During the last seven years of the period he was its District Engineer for that State.

It appears that, in the hydraulic branch of the Profession, Mr. Clapp found the work for which he was best fitted by inclination and experience. He had grown up in a region in which the agricultural possibilities are limited only by the available water supply and the skill with which it is conserved and applied. He had encountered, during his entire professional life, all the difficult engineer-

* Memoir prepared by M. O. Leighton, M. Am. Soc. C. E.

ing problems that beset an arid country. Even while engaged in other lines of engineering work, he had been constantly in touch with water-supply developments and the problems in relation thereto. Therefore, when he entered the Federal service he was mature in hydraulic matters, and his work was productive from the very beginning. Within a short time his reports and opinions were regarded as authoritative, and were accepted as *prima facie* evidence in the Courts of California.

Although, by reason of the distance from his headquarters to New York City, Mr. Clapp rarely found an opportunity to take part in any of the meetings of the Society, his interest in it was profound, and he took singular pride in his membership. His principal contribution to the publications of the Society* was a study of the Sacramento River flood of March, 1907, written in collaboration with E. C. Murphy, M. Am. Soc. C. E., and W. F. Martin, Assoc. M. Am. Soc. C. E.

The study and analysis of this disastrous flood was attended by unusual complications. In few, if any, recent inundations of this kind have consequences of greater magnitude been dependent on the correct interpretation of obscure evidence. Sacramento floods have been a perplexing problem throughout California history, and have been investigated repeatedly by able engineers in search of suitable measures of relief. A short time before the flood of 1907 extensive plans had been proposed by a competent Board of Engineers for reclaiming the enormous agricultural values of the Sacramento Basins and preventing further flood destruction. The study by Mr. Clapp and his associates demonstrated that those plans provided for less than half the capacity necessary to achieve the desired purpose. Substantial evidence of the accuracy of the work is contained in a recent report of a Board of Army Engineers, designated, under the authority of an Act of Congress, to make a complete investigation and submit a report on a plan for the control of floods in the Sacramento and San Joaquin Valleys. This report contains the following statement:

"It is thought that the estimates of Messrs. Clapp, Murphy, and Martin should be followed very closely in determining the necessary channel widths, and their maximum is assumed with certain allowances for flattening of the flood wave in passing down the improved channels."

In the progressive development of the State of California, so dependent on the wise utilization of its water supplies, it is evident that, as valuable as Mr. Clapp's work now appears, it has not begun to accomplish that which it finally will. In the future, more than in the present or past, the great hydraulic developments of that State will be guided in large measure by the observations and fundamental records that this quiet but forceful man has given to the people.

* *Transactions*, Am. Soc. C. E., Vol. LXI, pp. 281-330.

Mr. Clapp died at his home in Pasadena, Cal., on December 27th, 1911. During the last half year of his life he was in the grasp of a hopeless malady, throughout the course of which he amply demonstrated the steadfast characteristics that marked the whole of his useful career. He was one of those men whose best qualities are exposed only to those who achieve their entire confidence. Without pretense or display, he was content to allow his acquaintances to base their personal appraisal on those of his qualities that could withstand the scrutiny of close association. That he had, under such a social and professional creed, gathered to himself a host of genuine friends is the most potent evidence that can be cited concerning his personal merits. Because he was a real out-of-door man, the majority of his friends were those whom he had encountered somewhere on the trail, where men quickly find their level, and friendship is a natural consequence among those who make good.

Mr. Clapp was elected a Member of the American Society of Civil Engineers on December 6th, 1905.

ALFRED FRANCIS SEARS, M. Am. Soc. C. E.*

Died June 7th, 1911.

Alfred Francis Sears, son of Zebina and Elizabeth Sears, was born in Boston, Mass., on November 10th, 1826. He was educated in the public schools of that city, and was graduated from the Winthrop School with a Franklin Medal in 1841, and from the English High School in 1844. Then, "by a mother's wisdom," as he has said, he was given a year's training in a merchant's counting-room.

In 1845, he entered an architect's office to begin his chosen profession, but, after a year of the close confinement of the drafting-room, the threatening danger of pulmonary disease compelled him to seek out-of-door employment, and he took up civil engineering. He often spoke with pride of having begun civil engineering work "at the head of a hundred-foot chain on the surveys for the Boston Water-Works."

In 1861, when the Civil War came upon the country, Mr. Sears was Engineer of Streets in Newark, N. J. He resigned in June of that year to raise a company, which, being completed in August, was taken to New York City and there incorporated in the First New York Engineers. His company sailed in October with the Expeditionary Corps, referred to at the time as the "The Great E. C." After a year of service in the field, during which, with his company, he assisted in the capture of Forts Walker and Beauregard, in Port Royal Bay, he was ordered to report to the Chief Engineer of the Army, at

* Memoir prepared by John T. Whistler, M. Am. Soc. C. E.

Washington, and was placed in charge of the construction of Fort Clinch, Fla., where he remained until November, 1865.

After the war he returned to Newark and was made Chief Engineer of what was then known as the Newark and New York Railroad, now a part of the New Jersey Central Railroad. In his autobiography Major Sears refers with special pride to his location of this line, and its final adoption, after bitter opposition on the part of most of the company. This line may be said to have been the first elevated railway in the United States.

In 1867, Major Sears was employed on the location of a trans-continental railway in Costa Rica, and in 1869 became associated with the late Henry Meiggs in its construction. In 1872 he was called by Mr. Meiggs to Peru, where he remained until 1880, when the war with Chili paralyzed public works. He returned to the United States, and, except for occasional employment and trips of short duration in Mexico, Peru, and Europe, and a short temporary residence in New York City, made his home in Portland, Ore., where his only son, Judge Sears, also recently deceased, resided.

In 1849 he was married to Augusta Bassett, of Bridgewater, Mass., who survives him. She is a very dear old lady and though 87 years of age and nearly blind, feels it to be her duty, as did her husband, to bear her troubles cheerfully and be no burden to any one, either socially or otherwise.

Some time before his death Major Sears wrote:

"Just now I am suffering a congestion of anniversaries, having passed the 83d of my birth, the 30th of my arrival in my Oregon home, and the 60th of my marriage. It is an interesting providence of my life, that, while my wife is so nearly blind she cannot see to read, and I am very deaf, she has excellent hearing and I have perfect eye-sight. So that we are the complement of each other, and together make the one being for which man and wife are intended."

He retained his brilliant and entertaining literary and conversational powers almost to the very end of his life. He was invariably cheerful, and usually had a bright little anecdote, however short, to illustrate some point in his conversation. Unlike so many men of this disposition, he had strong convictions and the courage to stand for them at all times. Nevertheless, he was charitable to any one with whose views he could not agree, only requiring that such contrary views be sincere.

Major Sears was a great reader and an ardent student. He read and spoke with great fluency French, Spanish, and Italian, and even in his ordinary conversation, he used the purest of English and the most delightful style.

On July 22d, 1865, he was called on to address the citizens of Nassau County, Florida, on the subject of "The Reorganization of the

State." As the circumstances seemed to require him to respond, he did so, and the address is almost a classic. The following brief quotation from this address illustrates at once his courage and his character:

"Now, if this plain talk hurts any man here who pretends to be loyal, I have only to say that he reminds me of a Jew, professing Christianity, who begged men not to speak harshly of Judas Iscariot because he was a countryman of his."

Major Sears was elected a Member of the American Society of Civil Engineers, on June 2d, 1869.

JOSEPH CANBY HADSALL, Assoc. M. Am. Soc. C. E.*

Died June 29th, 1911.

Joseph Canby Hadsall, the son of Mollie J. (Hunt) and John Edward Hadsall, was born in Pleasant Valley, W. Va., on April 20th, 1873. He received his early education in the schools at Bethany, W. Va., and in 1892 was graduated from the Normal School at West Liberty, W. Va. For two years, 1898-1900, he studied architecture and civil engineering at Columbian University, Washington, D. C.

Mr. Hadsall was employed as Assistant on city work with J. F. Burley and Brother, at Moundsville, W. Va. This was followed by office and field work with the South Penn Oil Company, and, later, by one year of private practice at Moundsville, W. Va., on municipal work and land surveys.

From 1898 to 1905 he was employed in the United States Treasury Department, and for several months in the latter year, in the United States Surveyor General's Office at Cheyenne, Wyo.

From 1905 to 1911, as Civil and Irrigation Engineer for the Wyoming Development Company and the Wheatland Industrial Company, he was responsible for the designs for an irrigation system for 90 000 acres of land, and had charge of all the engineering work. He also designed and constructed the water-works, sewerage, and electric light systems of Wheatland, Wyo.

In June, 1902, he was married to Miss Frances Luttrell, of Knoxville, Tenn., who with a son, Joseph Vernon, survives him.

Mr. Hadsall was a man of sterling character and strict integrity. He won the esteem and respect of all who knew him, and always stood for the highest and best interests of the community. He was a member of the Protestant Episcopal Church.

Mr. Hadsall was elected an Associate Member of the American Society of Civil Engineers on November 8th, 1909.

---

*Memoir prepared by H. B. Patten M. Am. Soc. C. E.

INDEX

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXVIII—No. 3

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

March, 1912

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXVIII—No. 3

MARCH, 1912

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS

NEW YORK 1912

American Society of Civil Engineers

OFFICERS FOR 1912

President, JOHN A. OCKERSON

Vice-Presidents

Term expires January, 1913:	*Term expires January, 1914:*
ALFRED P. BOLLER	CHARLES S. CHURCHILL
CHARLES L. STROBEL	CHARLES D. MARX

Secretary, CHARLES WARREN HUNT

Treasurer, JOSEPH M. KNAP

Directors

Term expires January, 1913:	*Term expires January, 1914:*	*Term expires January, 1915:*
WILLIAM E. BELKNAP	GEORGE C. CLARKE	LINCOLN BUSH
HORACE LOOMIS	CHARLES W. STANIFORD	T. KENNARD THOMSON
GEORGE A. KIMBALL	JONATHAN P. SNOW	EMIL GERBER
PERCIVAL ROBERTS, JR.	ROBERT RIDGWAY	WILLIAM CAIN
CHARLES F. LOWETH	LEONARD W. RUNDLETT	E. C. LEWIS
ARTHUR DEWINT FOOTE	WILLIAM H. COURTENAY	W. A. CATTELL

Assistant Secretary, T. J. McMINN

Standing Committees

(THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES)

On Finance:	*On Publications:*	*On Library:*
LINCOLN BUSH	WILLIAM E. BELKNAP	ALFRED P. BOLLER
HORACE LOOMIS	ROBERT RIDGWAY	CHARLES D. MARX
CHARLES W. STANIFORD	CHARLES S. CHURCHILL	EMIL GERBER
GEORGE A. KIMBALL	CHARLES L. STROBEL	CHARLES F. LOWETH
PERCIVAL ROBERTS, JR.	JONATHAN P. SNOW	CHAS. WARREN HUNT

Special Committees

ON CONCRETE AND REINFORCED CONCRETE: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

ON ENGINEERING EDUCATION: Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead.

ON STEEL COLUMNS AND STRUTS: Austin L. Bowman, Alfred P. Boller, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

ON BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER....................5913 Columbus.
CABLE ADDRESS...................."Ceas, New York."

Vol. XXXVIII. MARCH, 1912. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

February 21st, 1912.—The meeting was called to order at 8.30 P. M.; A. L. Bowman, M. Am. Soc. C. E., in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 138 members and 22 guests.

A paper entitled "The Problem of the Lower West Side Manhattan Water-Front of the Port of New York," by B. F. Cresson, Jr., M. Am. Soc. C. E., was presented by the author and illustrated with lantern slides.

The paper was discussed by Messrs. T. Kennard Thomson, S. W. Hoag, Jr., H. McL. Harding, James Forgie, G. W. Kittredge, Calvin Tomkins, E. C. Moore, and Charles H. Higgins. A communication on the subject, from Edlow W. Harrison, M. Am. Soc. C. E., was presented by the Assistant Secretary.

The Assistant Secretary announced the following deaths:

Walter A. Post, elected Member March 1st, 1893; died February 11th, 1912.

William Chattin Wetherill, elected Member December 1st, 1886; died February 10th, 1912.

Adjourned.

March 6th, 1912.—The meeting was called to order at 8.45 P. M.; Director T. Kennard Thomson in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 93 members and 6 guests.

The minutes of the Annual Meeting, January 17th, and of the meeting of February 7th, 1912, were approved as printed in *Proceedings* for February, 1912.

A paper by N. B. Sweitzer, Assoc. M. Am. Soc. C. E., entitled "Retracement-Resurveys—Court Decisions and Field Procedure," was presented by the Assistant Secretary, who also read communications on the subject from Messrs. W. Newbrough and J. Francis Le Baron. The paper was discussed orally by J. L. Davis, Assoc. M. Am. Soc. C. E.

The Assistant Secretary announced the election of the following candidates on March 5th, 1912:

As Members

George Booth Baskervill, Jr., Macon, Miss.
William Benjamin Bennett, Harrisburg, Pa.
Charles Perry Chase, Clinton, Iowa
Ernest Alden Clark, Chicago, Ill.
Howard Lincoln Coburn, Boston, Mass.
Harry Cyrus Hill, Concord, N. H.
Ulysses Stanislaus Lutz, Brooklyn, N. Y.
George William Volckman, Ottawa, Ont., Canada

As Associate Members

Edgar Harold Annear, Modesto, Cal.
Frank Willis Austin, Hartford, Iowa
Ralph Pitcairn Barnett, Hempstead, N. Y.
Harold Hendryx Barter, Reno, Nev.
William Webster Chadsey, Schenectady, N. Y.
Arthur Lee Collins, San Francisco, Cal.
Harry Custer Diesem, Richfield, Idaho
Henry Gerharz, Billings, Mont.
Richard Frederick Hoffmark, Nome, Alaska
Albert Woodbridge Pioda, San Francisco, Cal.
Reuben Lynn Rockwell, Downey, Idaho
Trygve Ronneberg, San Francisco, Cal.
Alexander Douglas Stark, Kearny, N. J.
Frank William Stephens, Guantanamo, Cuba
George Edward Vansittart, Boise, Idaho

As Associates

Charles Augustus Jennings, Chicago, Ill.
Harold Beggs Pullar, Chicago, Ill.

As Juniors

Lyttleton Cooke Anderson, Memphis, Tenn.
Harold Wallace Baker, Georgetown, Del.
Alec Edward Brook, Sheffield, England
Robert William Burrowes, Long Beach, N. Y.
George Bache DuBois, Philadelphia, Pa.
Harold Lewis English, Hanover, N. H.
Frank Sampson Mason Harris, Oakland, Cal.
Arthur Kraus, New York City
Lawrence Vinnedge Sheridan, Indianapolis, Ind.
Frank Burns Storey, Portland, Ore.
Seneca Vern Taylor, Massena, N. Y.
Charles Edward Thornton, Empire, Canal Zone, Panama

The Assistant Secretary announced the transfer of the following candidates on March 5th, 1912:

From Associate Member to Member

Charles Joseph Carroll, Durango, Mexico
George Hewitt, New York City
Robert Summers Stockton, Strathmore, Alta., Canada
Henry Amerman Young, New York City

From Junior to Associate Member

Lou Baker Cleveland, Watertown, N. Y.
Arthur Wellesley Coombs, New York City
Jay Allen Craven, Indianapolis, Ind.
Arthur James Decker, Ann Arbor, Mich.
Roger DeLand French, Montreal, Que., Canada
Herbert Miller Hale, New York City
John Philip Hogan, High Falls, N. Y.
George Cheney Newton, Milwaukee, Wis.

The Assistant Secretary announced the following deaths:

John Herron, elected Member, October 4th, 1893; died February 2d, 1912.

T. Guilford Smith, elected Member, September 6th, 1871; died February 20th, 1912.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract)

March 5th, 1912.—Past-President Bates in the chair; T. J. McMinn, Asst. Secretary, acting as Secretary; and present, also, Messrs. Belknap, Bensel, Bush, Endicott, Gerber, Knap, Loomis, Loweth, Ridgway, Roberts, Snow, Staniford, and Thomson.

Tuesday, June 4th, 1912, was chosen as the time for the opening session of the Annual Convention.

The resignations of 3 Juniors and 1 Associate were accepted.

Ballots for membership were canvassed, resulting in the election of 8 Members, 15 Associate Members, 2 Associates, and 12 Juniors, and the transfer of 8 Juniors to the grade of Associate Member.

Four Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

April 3d, 1912.—8.30 P. M.—This will be a regular business meeting. A paper by Louis H. Shoemaker, M. Am. Soc. C. E., entitled "A Four-Track Center-Bearing Railroad Draw Span," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

April 17th, 1912.—8.30 P. M.—At this meeting a paper by Burgis G. Coy, Assoc. M. Am. Soc. C. E., entitled "The Laramie-Poudre Tunnel," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

May 1st, 1912.—8.30 P. M.—A regular business meeting will be held, and a paper entitled "Faults in the Theory of Flexure," by Henry S. Prichard, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION

The Forty-fourth Annual Convention will be held at Saratoga, N. Y., June 4th, 1912.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society, in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Gavin N. Houston, M. Am. Soc. C. E., 409 Equitable Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all Meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From February 10th to March 9th, 1912)

DONATIONS *

THE ECONOMICS OF CONTRACTING.

A Treatise for Contractors, Engineers, Superintendents and Foremen Engaged in Engineering Contracting Work. By Daniel J. Hauer. Cloth, $8\frac{3}{4}$ x $5\frac{1}{2}$ in., illus., 269 pp. Chicago, E. H. Baumgartner, 1911. $2.50.

It is stated in the preface that this book is a study of the principles and history of the business of contracting, the author using his own experience and knowledge gleaned from others as a basis. The subject-matter relates to the fundamentals affecting the economics of the contracting business, as well as methods, equipment, and organization used in modern construction work. The author hopes that the older contractors may find in the treatise some thoughts and ideas that may be useful, and that the younger men may learn how to guard against both loss of time and money in eliminating mistakes made by others. The Contents are: Contracting as a Profession; Forms of Contract; Proposals, Bonds, Arbitration, and Other Features of Contracts; The Business End of Contracting; The Clerical End of Contracting; Contractors' Workmen; Construction Camps; The Management of Contracts; Contractors' Outfit and Plant; A Personal Chapter for the Contractor; Addena: Changing Plans After a Contract is Awarded; Onerous Specifications; Books for Contractors.

A LABORATORY MANUAL OF PHYSICS AND APPLIED ELECTRICITY.

Arranged and Edited by Edward L. Nichols. Vol. I, Junior Course in General Physics, Revised and Rewritten by Ernest Blaker. Cloth, 9 x 6 in., illus., 13 + 417 pp. New York, The Macmillan Company, 1912. $3.00.

As a result of the changes which have been made in the treatment of many of the experiments included in the first edition of this book, the present edition of Volume I of this Manual is stated to have been almost entirely rewritten, a few of the earlier experiments having been omitted and about forty new ones having been added. In the preface to the first edition, it is stated that this volume is intended for beginners in laboratory work, who possess some knowledge of analytical geometry and calculus and who have completed a textbook and lecture course in the principles of physics, and that it includes explicit directions, together with demonstrations and occasional elementary statements of principles, no attempt being made to include the whole of physics. In the Introduction it is stated that the object of the experiments described is to illustrate the principles and laws previously learned from textbooks and lectures and to familiarize the student with proper methods of observation and physical experimentation. The Chapter headings are: Introduction; Curvature of a Lens by the Spectrometer, etc.; General Statements Concerning Density; General Statements Concerning Calorimetry; Radius of Curvature by Reflection, etc.; General Statements Concerning Photometry; Measurement of Pitch by the Syren, etc.; General Statements Concerning Static Electricity; General Statements Concerning Magnetism; General Statements Concerning the Electric Current; General Statements Concerning Difference of Potential and Electromotive Force; General Statements Concerning Resistance; General Statements Concerning Electrical Quantity; General Statements Concerning Induction; General Statements Concerning the Magnetic Properties of Iron; Tables; Index.

PORTLAND CEMENT

Its Composition, Raw Materials, Manufacture, Testing and Analysis. By Richard K. Meade. Second Edition. Cloth, 9 x 6 in., illus., 10 + 512 pp. Easton, Pa., The Chemical Publishing Co.; London, Williams & Norgate, 1911. $4.50.

The first edition of this book was published in 1906, and for the present edition, the author states that the entire text has been revised. After an Introduction, the author discusses the manufacture of Portland cement and describes the various appliances used in this connection, stating that this section represents fairly

* Unless otherwise specified, books in this list have been donated by the publisher.

well the present state of the industry in the United States. The subject-matter relating to the Analytical Methods described, has been increased. These methods have been used to some extent in the author's laboratory and have been found satisfactory. Under the heading "Notes," comments as to its accuracy and advice as to the best method of manipulation are added to each method described. The section on Physical Testing has been revised, it is stated, to conform to the changes made in the standard specifications and methods of testing, much new matter having been added. Under the section, Miscellaneous, the author discusses adulteration in Portland cement and has added a new chapter relating to the investigation of materials used in its manufacture. The Contents are: Introduction: Relation Between Mortar Materials and History of the Development of the American Portland Cement Industry; The Nature and Composition of Portland Cement. Manufacture: Raw Materials; Proportioning the Raw Materials; Quarrying, Excavating, Drying, and Mixing the Raw Materials; Grinding the Raw Materials and Grinding Machinery; Burning-Kilns and Process; Burning-Fuel and Preparation of the Same; Cooking and Grinding the Clinker; Storing and Packing the Cement, etc. Analytical Methods: The Analysis of Cement; The Analysis of Cement Mixtures; Analysis of the Raw Materials. Physical Testing: The Inspection of Cement; Specific Gravity; Fineness; Time of Setting; Tensile Strength; Soundness. Miscellaneous: The Detection of Adulteration in Portland Cement; The Investigation of Materials for the Manufacturing of Portland Cement. Appendix: Tables; Index.

AËRIAL NAVIGATION.

A Popular Treatise on the Growth of Air Craft and on Aëronautical Meteorology. By Albert Francis Zahm. Cloth, $8\frac{1}{4} \times 5\frac{1}{2}$ in., illus., 17 + 497 pp. New York and London, D. Appleton and Company, 1911. $3.00.

The purpose of this work, it is stated, is to portray in popular terms the substantial progress of aeronautics from its earliest beginning to the present time. Experiments which constitute no advance in the art or have led to no useful result, are not included except in the introductory chapter. After describing the evolution of aeronautics, the author gives a brief account of the general properties of the air which affect its density and also of the generation and prevalence of the great currents of the atmosphere and the local winds and invisible turmoils which concern the safety and effective progress of the aviator. French units of measurement are used as well as English ones, as the official rules and records of international aeronautic events are partly expressed in the metric system. The Appendices are stated to contain interesting historical facts and much quantitative data of interest to the technical and special student. The Contents are: Introduction; Part I, Growth of Aerostation: Early History of Passive Balloons; Practical Development of Passive Balloons; Early History of Power Balloons; Introduction of Gasoline-Driven Dirigibles; Practical Development of Non-Rigid Dirigibles; Development of Rigid Dirigibles. Part II, Growth of Aviation: Model Flying Machines; Nineteenth Century Man-Flyers; Aeroplanes of Adequate Stability and Power; Advent of Public Flying; Strenuous Competitive Flying; Forcing the Art. Part III, Aeronautic Meteorology: General Properties of Free Air; General Distribution of Heat and Pressure; Permanent and Periodic Winds; Cyclones, Tornadoes, Water Spouts; Thunderstorms, Wind Gusts. Appendices: Stress in a Vacuum Balloon; Aeronautic Letters of Benjamin Franklin; Successful Military Dirigible Balloons; The Relations of Weight, Speed, and Power of Flyers; Curtiss' Hydro-Aeroplane Experiments; Index.

A MANUAL OF ENGINEERING DRAWING

For Students and Draftsmen. By Thomas E. French. Cloth, $9\frac{1}{4} \times 6$ in., illus., 11 + 289 pp. New York, McGraw-Hill Book Company, 1911. $2.00.

The author defines Engineering Drawing as the language used in the industrial world by engineers and designers to express and record the ideas and information necessary for the building of machines and structures, and by the aid of which every necessary operation is minutely described and complete records kept for duplication or repairs. When done with the aid of mathematical instruments, it is called Mechanical Drawing, which, it is stated, develops accuracy of measurement and manual dexterity; when done without the assistance of instruments or appliances, it is known as Technical Sketching which trains the student to comprehensive observation and gives him control and mastery of form and proportion. The author states that the first step in the study of Engineering Drawing is familiarity with the necessary instruments and ability to use them correctly, after which the student's whole energy should be directed toward training in construc-

tive imagination, as his success will depend not only on his skill in execution, but also on his ability to interpret his impressions, to visualize quickly and accurately. As the best illustrations of principles described, the author has used machine parts, and he has also added chapters on architectural and map drawing, as it is necessary for every engineer to be able to read and work from such drawings. The Chapter headings are: Introductory; The Selection of Instruments; The Use of Instruments; Applied Geometry; Lettering; Orthographic Projection; Developed Surfaces and Intersections; Pictorial Representation; Working Drawings; Technical Sketching; The Elements of Architectural Drawing; Map and Topographical Drawing; Duplication, and Drawing for Reproduction; Notes on Commercial Practice; Bibliography of Allied Subjects; Index.

THE PRACTICAL GAS AND OIL ENGINE HAND-BOOK.

A Manual of Useful Information on the Care, Maintenance and Repair of Gas and Oil Engines. By L. Elliott Brookes. Cloth, $6\frac{3}{4}$ x $4\frac{1}{2}$ in., illus., 192 pp. Chicago, Frederick J. Drake & Co., 1911. $1.00.

The author's intention in this book is to furnish practical information regarding the construction, operation, and management of gas, gasoline, and kerosene engines, and he states that it gives full instructions on all points relating to the care, maintenance, and repair of stationary, portable, marine and automobile, gas and oil engines, including how to start, how to stop, how to adjust, how to repair, and how to test them. The information is said to be presented in a clear and practical manner, all technical matter being avoided as far as possible.

STORAGE BATTERIES.

The Chemistry and Physics of the Lead Accumulator. By Harry W. Morse. Cloth, $7\frac{1}{2}$ x 5 in., illus., 266 pp. New York, The Macmillan Company, 1912. $1.50.

In his introductory chapter the author states that a study of the storage battery has two rather distinct viewpoints of nearly equal importance, namely, chemical and physical, questions about the fundamental reactions being purely chemical and must be kept in mind in manufacture and operation, while questions of the life of the cell and its behavior in service are physical and of prime importance. The viewpoints are discussed by the author, but no attempt has been made to give any details of storage battery engineering, the peculiarities of the cell itself only being described for the reader's benefit. It is stated that the subject-matter is based on lectures given for the last few years at Harvard University, in a course in which the work on storage cells is preceded by study of the general theory of galvanic cells, and the simplest of this theory has been included in the book. The Contents are: Introductory and Historical; Some Electrochemical Fundamentals; About Ions; The Fundamental Cell-Reaction; The Active Ions; Some Pertinent Physical Queries; Energy Relations; Reactions at the Electrodes; Charge and Discharge; Capacity; Efficiency; Internal Resistance; Physical Characteristics; Formation of Planté Plates; Paste Plates; Diseases and Troubles; Some Commercial Types; Accumulators in General; Appendix; Index.

CEMENT PIPE AND TILE.

Advantages of Cement for Pipe and Tile, Methods of Manufacture, Tests, Cost, etc. By E. S. Hanson. Second Edition. Cloth, $7\frac{3}{4}$ x 5 in., illus., 153 pp. Chicago, The Cement Era Publishing Company, 1911. $1.00. (Donated by the Author.)

The author's aim has been to bring together, as far as possible, in one place all matter relating to each phase of the cement pipe and tile industry, and he hopes the book will be useful in the upbuilding of what he believes is destined to be one of the most important lines of endeavor in the use of cement. Like the previous edition issued less than three years ago, the work is stated to be largely a compilation, but, owing to the rapid development of the industry, it differs widely from the first edition, and includes much information gathered by the author from personal visits to many pipe and tile plants. The Contents are: Introduction; Advantages of Cement for Pipe and Tile; Concrete Pipe Sewers; Pipe for Pressure Service; Concrete Pipe for Culverts; Establishing a Plant; The Materials Required; Methods of Manufacture; Curing; The Matter of Costs; Tests; Machines and Systems on the Market (Present-Day Systems Illustrated and Reviewed); Index.

ENGINEERING AS A VOCATION.

By Ernest McCullough, M. Am. Soc. C. E. Cloth, $8\frac{1}{4}$ x $5\frac{1}{2}$ in., illus., 201 pp. New York, David Williams Company, 1911. $1.00.

The preface states that the subject-matter contained in this book was first given as a series of addresses before technical schools and engineering assistants. The author has rearranged and added to the text and states that it is issued in book form "for the information of parents in order that they may act wisely in selecting careers for their sons." He outlines the personal qualities necessary to a successful engineer, the work that will be required of him, his education, comparing the American system with that of Europe, etc., and states that his opinions in regard to wholesale technical education do not coincide with those generally found in semi-technical periodicals and daily newspapers. The Chapter headings are: The Engineer; The Work of the Engineer; The Education of the Engineer; Home Study Courses; How to Hunt and Hold a Job; Does It Pay to Study Engineering?; The Opinions of Engineering Editors.

COMMISSION GOVERNMENT IN AMERICAN CITIES.

By Ernest S. Bradford. Cloth, $7\frac{1}{2}$ x 5 in., illus., 14 + 359 pp. New York, The Macmillan Company, 1911. $1.25.

Of the recent developments in the field of municipal politics the author states that none has attracted more attention than the introduction and rapid rise of the Commission Form of city government, so-called from the commission or board which constitutes the governing body. Starting in 1900 in Galveston, Tex., the idea has spread from the Gulf to the North Central States, to New England, and to the Pacific Coast, and in August, 1911, it is stated that more than 150 American cities of varying population and representing all sections had adopted the Commission Form of government, with modifications and additions to suit local conditions. The aim of this book is to inquire as to the rise of the plan, the reasons for its adoption by the various municipalities, and the degree of success attained in such municipalities. An analysis of the idea into its elements has also been made, as well as an attempt to account for certain of the results which have followed its adoption, and it is hoped that the data here presented may throw some light on the workings of the plan as far as adopted. The Contents are: Part I, Spread of the Commission Form: Galveston; Houston; Des Moines; Cedar Rapids; Cities of Kansas; States of Upper Mississippi Valley; Texas and Oklahoma; Massachusetts; West Virginia, Tennessee, and the South; Colorado and the Pacific States, Preferential Voting; Summary of Commission Cities; The Business City Manager—Staunton, Va. Part II, A Comparison of Forms of Commission Government: Commission Government, Essential Features; The Small Board; Election at Large, A Redefinition of Representation; Concentration of Municipal Authority; Each Commissioner Head of a Department; "Checks"; Publicity; Referendum and Initiative; The Recall; Non-partisan Primaries and Elections, Preferential Voting; Municipal Civil Service, Other Provisions; Summary of "Checks," Classification of Commission Cities; Unusual and Partial Forms of Commission Government; Limitations of the Commission Form; Objections to Commission Government; Conclusion; Preferential Ballot Provisions of Grand Junction; Text of Iowa Law (Des Moines Plan); List of References; Index.

COMMISSION GOVERNMENT IN AMERICAN CITIES.

The Annals of the American Academy of Political and Social Science, Vol. XXXVIII, No. 3, November, 1911. Emory R. Johnson, Editor. Paper, 10 x 7 in., illus., 6 + 273 pp. Philadelphia, The American Academy of Political and Social Science, 1911. $1.00.

This work is the fifth of a series of studies on municipal government issued by the Academy and was planned by Dr. Clyde L. King, of the Department of Political Science in the University of Pennsylvania. This collection of papers by men who have studied the question, is believed, it is stated, to be of special value on a subject of wide interest and permanent import. The Contents are: Part I, Underlying Principles and Typical Plans; Part II, Problems of Commission Government; Part III, Objections, Limitations and Modifications of the Plan; Part IV, Results of Commission Government in Typical Cities.

THE ESSENTIALS OF LETTERING.

A Manual for Students and Designers. By Thomas E. French and Robert Meiklejohn. Third Edition, Revised and Enlarged. Cloth, $6\frac{1}{4}$ x 9 in., illus., 7 + 94 pp. New York and London, McGraw-Hill Book Company, 1912. $1.00.

This book is designed, it is stated, as a general textbook on the subject of lettering, and is intended for art students, artists, designers, etc., as well as for engineering students, draftsmen, and architects. For the student who expects to do

serious work on lettering, it is said to be only an introduction, the author's aim being to give an adequate number of practical working styles for the ordinary draftsman and designer, with examples of composition in sufficient variety to illustrate the text. The first four chapters are devoted to the fundamental forms of lettering as used in office drawings and the rules on which they are based. The remaining chapters are intended for the use of the designer. There is a bibliography containing a list of books for those who desire to study the subject further, some of which are especially adapted for the designer's library. The Contents are: Historical Outline; Letter Construction; Composition and Titles; Selection of Styles; Letters in Design; Design and Composition; Monograms, Ciphers and Marks; Drawing for Reproduction; Bibliography; Index.

Gifts have also been received from the following:

Aberthaw Constr. Co. 1 pam.
Aldershot, England, Gas, Water & District Lighting Co. 1 pam.
Am. Elec. Ry. Assoc. 1 bound vol.
Am. Soc. C. E., San Francisco Assoc. 1 pam.
Am. Soc. of Mech. Engrs. 1 bound vol.
Assoc. of Am. Portland Cement Mfrs. 1 vol.
Assoc. of Transportation and Car Accounting Officers. 1 pam.
Baltimore County, Md.-Roads Engr. 1 pam.
Boston, Mass.-Transit Comm. 1 bound vol.
Brockton, Mass.-Water Commrs. 1 pam.
Caird, James M. 1 pam.
Cambrian Rys. Co. 1 pam.
Canada-Dept. of Marine and Fisheries. 2 vol.
Carson, W. W. 2 pam.
Central London Ry. Co. 1 pam.
Chicago, Ill., Bureau of Public Efficiency. 2 pam.
Connecticut-R. R. Commr. 1 bound vol.
Daily Record Co., The. 1 pam.
Essex County, Mass.-Engr. 1 pam.
Fall River, Mass.-Watuppa Water Board. 1 pam.
Furness Ry. Co. 1 pam.
Great Britain-Patent Office. 3 vol.
Great Central Ry. Co. 1 pam.
Great Northern Ry. Co. 1 pam.
Great Western Ry. Co. 1 pam.
Hull & Barnsley Ry. Co. 1 pam.
Hyde, C. G. 3 pam.
Illinois-Bureau of Labor Statistics. 1 pam.
Illinois Assoc. of Drainage and Levee Districts. 1 pam.
Illinois, Univ. of-Agri. Exper. Station. 3 pam.
Inst. of Industrial Research. 1 pam.
Institution of Gas Engrs. 1 bound vol.
Institution of Naval Archts. 1 bound vol.
Iowa-Auditor of State. 1 bound vol.
Lake Michigan Water Comm. 1 bound vol.
Lakes-to-the-Gulf Deep Waterway Assoc. 1 pam.
Leominster, Mass.-Water Board. 1 pam.
Liverpool Eng. Soc. 1 bound vol.
Liverpool Overhead Ry. Co. 1 pam.
Maine-Dept. of Vital Statistics. 1 bound vol.
Manchester, Mass.-Sewerage Committee. 1 pam.
Maryport & Carlisle Ry. Co. 1 pam.
Mass. Inst. of Tech. 1 pam.
Mexican Southern Ry. Co., Ltd. 1 pam.
Michigan-State Board of Health. 1 bound vol.
Michigan-State Insp. of Illuminating Oils. 1 pam.
Midland & South Western Junction Ry. Co. 1 pam.
Midland Ry. Co. 1 pam.
Milwaukee, Wis., Bureau of Economy and Efficiency. 2 pam.
Minnesota-State Board of Health. 1 bound vol.
National Board of Fire Underwriters. 2 pam.
National Irrig. Congress. 1 vol.
New Bedford, Mass.-Water Board. 1 pam.
New York City-Board of Water Supply. 1 pam.
New York City-Dept. of Health. 1 pam.
Newport, England-Water-Works Dept. 1 pam.
North London Ry. Co. 1 pam.
North Staffordshire Ry. Co. 1 pam.
Northampton, Mass.-Board of Water Commrs. 1 pam.
Oregon-State Board of Health. 1 pam.
Oesterreichischer Ing. und Architekten-Verein. 1 pam.
Pennsylvania-Dept. of Mines. 2 bound vol.
Pere Marquette R. R. Co. 1 pam.
Philippine Islands-Bureau of Forestry. 1 pam.
Reading, Mass.-Water Commrs. 1 pam.
Rhode Island-Commrs. of Shell Fisheries. 1 pam.
Rhode Island-R. R. Commr. 1 bound vol.
Rhymney Ry. Co. 1 pam.
Schiffbautechnische Gesellschaft. 1 bound vol.
Smith, Earl B. 1 pam.
Smithsonian Institution. 12 pam.
Société Belge des Ingénieurs et des Industriels. 1 pam.
Southern Pacific Co. 1 pam.
Taunton, Mass.-Water Commrs. 1 pam.
U. S.-Bureau of Public Health, Marine Hospital Service. 1 vol.
U. S.-Bureau of the Census. 4 bound vol., 1 pam.
U. S.-Chf. of Engrs. 15 specif.
U. S.-Coast and Geodetic Survey. 1 bound vol., 1 pam.
U. S.-Commr. of Corporations. 1 pam.
U. S.-Interstate Commerce Comm. 1 bound vol., 5 pam.
U. S.-Naval Observatory. 1 bound vol.
U. S.-Navy Dept. 1 pam.
U. S.-Office of Exper. Stations. 2 pam.
U. S.-Office of Public Roads. 3 pam.
U. S.-Philippine Comm. 1 bound vol.
Virginia-State Highway Commr. 1 pam.
Webb Publishing Co. 1 pam.
Wisconsin-Geol. and Natural History Survey. 1 bound vol., 1 pam.
Woodworth, R. B. 1 pam.

BY PURCHASE

The Testing of Motive-Power Engines, Including Steam Engines and Turbines, Locomotives, Boilers, Condensers, Internal Combustion Engines, Gas Producers, Refrigerators, Air Compressors, Fans, Pumps, etc. By R. Royds. Longmans, Green and Co., New York and London, 1911.

The Irrigation of Mesopotamia. By Sir W. Willcocks. 2 Vol. Spon & Chamberlain, New York; E. & F. N. Spon, London, 1911.

Naval Architecture. By Cecil H. Peabody. Third Edition, Revised and Enlarged. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1911.

Modern Practice in Mining: Vol. IV, The Ventilation of Mines. By R. A. S. Redmayne. Longmans, Green and Co., New York and London, 1911.

American Society for Testing Materials: Proceedings of the Fourteenth Annual Meeting Held at Atlantic City, N. J., June 27th–July 1st, 1911. Vol. XI. University of Pennsylvania, Philadelphia, 1911.

Poor's Manual of Railroads of the United States Street Railway and Traction Companies. Forty-fourth Annual Number. Poor's Railroad Manual Co., New York, 1911.

The Magnetic Circuit. By V. Karapetoff. McGraw-Hill Book Company, New York and London, 1911.

The Induction Motor. By Benjamin F. Bailey. McGraw-Hill Book Company, New York and London, 1911.

Metallurgy: Vol. I, Introductory. By Herbert Lang. McGraw-Hill Book Company, New York and London, 1911.

Centrifugal Pumps: Their Design and Construction. By Louis C. Lowenstein and Clarence P. Crissey. D. Van Nostrand Company, New York, 1911.

Der Städtische Tiefbau: Band I, Die Städtischen Strassen, von Ewald Genzmer (2 vol.); Band III, Die Städtereinigung, von F. W. Büsing; Band V, Zweites Heft, Die Versorgung der Städte mit Electricität, von Oskar von Miller. Arnold Bergsträsser, A. Kroner, Stuttgart, 1897–1903.

SUMMARY OF ACCESSIONS

(From February 10th to March 9th, 1912)

Donations (including 4 duplicates)	152
By purchase	15
Total	167

MEMBERSHIP

ADDITIONS

(From February 12th to March 9th, 1912)

MEMBERS		Date of Membership.
BENNETT, WILLIAM BENJAMIN. Cons. Engr., 711 Telegraph Bldg., Harrisburg, Pa		Mar. 5, 1912
COBURN, HOWARD LINCOLN. Designing Engr., Ambursen Hydr. Constr. Co., 88 Pearl St., Boston, Mass		Mar. 5, 1912
COE, CLARENCE STANLEY. Div. Engr., Middle Div., Florida East Coast Ry., Pigeon Key Office, Marathon, Fla		Feb. 6, 1912
CONKLING, LEON DE VERE. Associate Prof. of Civ. Eng., Lehigh Univ., South Bethlehem, Pa	Assoc. M.	Dec. 4, 1901
	M.	Feb. 6, 1912
DICKEY, JOHN LEO. U. S. Engr. Office, Custom House, New Orleans, La		Feb. 6, 1912
GILCHRIST, CHARLES ALLYN. St. Martins, East, Philadelphia, Pa		Dec. 5, 1911
HARDING, JAMES CLARK. Member of Firm of George W. Fuller, 170 Broadway, New York City		Jan. 2, 1912
HEINDLE, WILLIAM ALBERT. Gen. Mgr. of Railways, Wilmington & Philadelphia Traction Co. and Southern Pennsylvania Traction Co., 603 Market St., Wilmington, Del	Assoc. M.	Nov. 6, 1901
	M.	Feb. 6, 1912
HILL, HARRY CYRUS. Concord, N. H		Mar. 5, 1912
HOWE, WILSON TYLER. Prin. Asst. Engr., Port Works, Manila, Philippine Islands		Dec. 5, 1911
JOYNER, FRANK HALL. 310 Palmetto Drive, Alhambra, Cal.		Sept. 5, 1911
MÖNNICHE, TOLLEF BACHE. Designing Engr., Isthmian Canal Comm., Culebra, Canal Zone, Panama	Assoc. M.	Oct. 3, 1906
	M.	Feb. 6, 1912
PARKER, JOHN CASTLEREAGH. Mech. and Elec. Engr., Rochester Ry. & Light Co., 34 North Clinton Ave., Rochester, N. Y	Jun.	Dec. 6, 1904
	Assoc. M.	May 6, 1908
	M.	Feb. 6, 1912
SMITH, WILSON FITCH. Div. Engr., Board of Water Supply of City of New York, Valhalla, N. Y	Jun.	Jan. 3, 1895
	Assoc. M.	May 1, 1901
	M.	Feb. 6, 1912
WIGGIN, THOMAS HOLLIS. Senior Designing Engr., Board of Water Supply, 165 Broadway, New York City	Assoc. M.	April 2, 1902
	M.	Feb. 6, 1912
WOOD, GEORGE. Asst. Engr., Pres., Borough of Richmond, 122 West 167th St., New York City	Assoc. M.	June 5, 1907
	M.	Feb. 6, 1912

ASSOCIATE MEMBERS		Date of Membership.
BIGGS, CARROLL ADDISON. Designer and Insp., Hydr. Turbines and Structural Steel, with William G. Fargo, 219 West Franklin St., Jackson, Mich.	Jun. Assoc. M.	Sept. 1, 1908 Feb. 6, 1912
BROWN, ROY HUNTLEY. Res. Engr., The Gres Falls Co., Cap de la Magdeleine, Que., Canada		Oct. 31, 1911
CLEVELAND, LOU BAKER. Civ. Engr. and Contr.; Chf. Engr., Carthage & Copenhagen R. R., Cleveland Bldg., Watertown, N. Y.	Jun. Assoc. M.	Sept. 1, 1908 Mar. 5, 1912
DELAY, THEODORE STUART. County Surv. and City Engr., Creston, Iowa		Feb. 6, 1912
EAGLESON, ERNEST GEORGE. City Engr., Boise, Idaho		Feb. 6, 1912
FOSTER, REGINALD GUY. 2124 Michigan Boulevard, Chicago, Ill		Feb. 6, 1912
FRANCIS, WILLIAM. Div. Engr., Dept. of Public Works, Virtudes 2ª, Havana, Cuba		Feb. 6, 1912
FULTON, WILLIAM LAWRENCE. Asst. Prof., Math. and Civ. Eng., Univ. of Vermont, 89 North Prospect St., Burlington, Vt		Oct. 3, 1911
GLOVER, PHILIP HOLDEN. Powell, Wyo		Feb. 6, 1912
HATCH, EVERETT HAMILTON. 142 Hugo St., San Francisco, Cal	Jun. Assoc. M.	Nov. 5, 1907 Dec. 5, 1911
HOLMES, NICHOLAS HANSON. Bldg. Supt., International Harvester Co. of Canada, Ltd., Hamilton, Ont., Canada		Jan. 2, 1912
HOLMES, ROBERT LESLIE. Div. Engr., Texas & Pacific Ry., Marshall, Tex	Jun. Assoc. M.	Oct. 1, 1907 Feb. 6, 1912
HOWES, FRANKLIN JOHNSON. Asst. Hydr. Engr., Rochester Ry. & Light Co., 34 North Clinton Ave., Rochester, N. Y.	Jun. Assoc. M.	June 1, 1909 Feb. 6, 1912
JOSLIN, HAROLD VINCENT. 330 Hillsboro St., Raleigh, N. C.	Jun. Assoc. M.	April 6, 1909 Feb. 6, 1912
KELTON, FRANK CALEB. Asst. Engr., Arizona Agri. Experiment Station, Tucson, Ariz		Feb. 6, 1912
KOPPELMAN, WILLIAM HOWARD. Constr., 415 Keller Bldg., Louisville, Ky		Feb. 6, 1912
LANE, CHARLES ELLIOT. Care, Snare & Triest, Zulueta 36 D, Havana, Cuba		Oct. 3, 1911
LEMEN, ROBERT WALKER. 965 Elsworth Ave., Columbus, Ohio		Jan. 2, 1912
McALLISTER, DANIEL HANDLEY. Asst. Gen. Supt. of Operation, Utah and Idaho Dept., Telluride Power Co., Provo, Utah		Sept. 5, 1911

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
NEAL, CLARENCE ADKINS. Secy., Union Bridge & Constr. Co., 903 Sharp Bldg., Kansas City, Mo.	Jun.	Dec. 6, 1904
	Assoc. M.	Feb. 6, 1912
PEASE, HAROLD TAPLEY. Chf. Engr. and Field Mgr., Arcadia Orchards Co., Deer Park, Wash.		Jan. 2, 1912
POSEY, GEORGE ADDISON. Asst. Engr., Haviland & Tibbetts, 228 Clayton St., San Francisco, Cal.		Feb. 6, 1912
PRICE, WILLIAM EDMUND. Engr. and Supt., S. A. Layton & S. Weymss Smith, Archts., 701 Majestic Bldg., Oklahoma, Okla.	Jun.	April 5, 1910
	Assoc. M.	Jan. 2, 1912
PRIOR, JOHN CLINTON. Asst. Engr., Dept. of Public Service, 405 Wilson Ave., Columbus, Ohio		Feb. 6, 1912
PRUETT, GROVER CLEVELAND. City Engr. and Supt., Water Plant, Box 161, Miles City, Mont.	Jun.	Mar. 2, 1909
	Assoc. M.	Feb. 6, 1912
RAMSEY, WILLIAM EVERTON. Engr., Concrete Steel Products Co., 6605 Harvard Ave., Chicago, Ill.		Feb. 6, 1912
RANDLETT, FRED MORSE. Asst. Engr., Water Board, City Hall, Portland, Ore.		Oct. 31, 1911
SIELING, LOUIS JOHN. 539 Linwood St., Brooklyn, N. Y.	Jun.	Feb. 1, 1910
	Assoc. M.	Feb. 6, 1912
STARR, REX CAMERON. 2344 Tulare St., Fresno, Cal.		Jan. 2, 1912
STEPHENS, GEORGE HIPPESLEY STANLEY. Care, Res. Engr., Caledon-Kykoedie Ry., Caledon, Cape Colony, South Africa		Dec. 5, 1911
STEVENS, LEIGH E. Asst. City Engr., 238 James St., Grand Rapids, Mich.		Feb. 6, 1912
TOPPING, PERRY. Asst. Engr., St. L. & S. F. R. R., 5870 Plymouth Ave., St. Louis, Mo.		Feb. 6, 1912
VOGEL, KARL EUGENE. Secy. and Supt., Omaha Structural Steel Works, 527 South 26th Ave., Omaha, Nebr.		Feb. 6, 1912
VON SILLER, ALFRED. 4446 Racine Ave., Chicago, Ill.		Sept. 5, 1911
WARE, NORTON. Dist. Engr., Reclamation Dist. 1 000, 531 Forum Bldg., Sacramento, Cal.		Dec. 5, 1911
WELLS, GEORGE EDWARD. Div. Engr., Benedict & Burnham Mfg. Co., Naugatuck, Conn.		Feb. 6, 1912

ASSOCIATES

HUBBARD, PREVOST. In Chg., Div. of Roads and Pavements, The Inst. of Industrial Research, 19th and B Sts., N. W., Washington, D. C.		Feb. 6, 1912
STEWART, LUCERN S. Pres., Union Bridge & Constr. Co., 903 Sharp Bldg., Kansas City, Mo.		Feb. 6, 1912

JUNIORS

	Date of Membership.
ANGWIN, HENRY RAYMOND. Draftsman, Haviland & Tibbetts, 1915 Market St., Oakland, Cal	Oct. 31, 1911
ARAKAWA, SANTARO. P. O. Box 1230, Stanford University, Cal	Feb. 6, 1912
BAKER, HAROLD WALLACE. Care, Coleman du Pont Rd., Georgetown, Del	Mar. 5, 1912
ENGLISH, HAROLD LEWIS. Hanover, N. H	Mar. 5, 1912
GRUNAUER, MORTIMER. 216 West 141st St., New York City.	Feb. 6, 1912
GUISSINGER, JOHN ADAM. Elaine, Ark	Sept. 5, 1911
HIRAI, KIKUMATSU. Care, Hokkaido Imperial Govt. Rys., Constr. Office, Asahigawa, Hokkaido, Japan	Dec. 5, 1911
KRAUS, ARTHUR. Structural Steel Works Draftsman, Public Works Dept., Navy Yard, 508 East 89th St., New York City	Mar. 5, 1912
NAJJAR, SIMON ABRAHAM. 94½ Greenwich St., New York City	Feb. 6, 1912
PHILLIPS, JAMES VERNON. Drainage Engr., U. S., Dept. of Agri., P. O. Box 592, Waycross, Ga	Feb. 6, 1912

CHANGES OF ADDRESS

MEMBERS

ALBERTSON, CHARLES. 727 Henry Bldg., Seattle, Wash.

ALLEN, WALTER HINDS. Civ. Engr., U. S. N., Navy Yard, Brooklyn, N. Y.

ARTHUR, HOWARD ELMER. Washington Inn, New Rochelle, N. Y.

BAKENHUS, REUBEN EDWIN. Civ. Engr., U. S. N.; Public Works Officer, Navy Yard, Boston, Mass.

BAUM, HARRY WILLIAM. Contr. Mgr., James Stewart & Co., 320 Newhouse Bldg., Salt Lake City, Utah.

BROWN, CHARLES OTTO. Cons. Engr., 165 South 9th St., Brooklyn, N. Y.

BROWN, PERCY FISHER. 482 Chetwood St., Oakland, Cal.

BROWN, WILLIAM MAXWELL. 1288 Commonwealth Ave., Boston, Mass.

BYAM, LE ROY HENRY. Secy. and Treas., The Elliot C. Brown Co., Room 3050, Grand Central Terminal, New York City.

COWLES, WALTER LINSLEY. Mead-Morrison Co., 751 Monadnock Bldg., Chicago, Ill.

CRANE, CLARENCE AUSTIN. Cons. Engr., 51 Chambers St., Room 930, New York City.

CROSWELL, THOMAS HENRY. Brainerd, Minn.

ELLIOTT, CHARLES GLEASON. 3934 Fourteenth St., N. W., Washington, D. C.

FLYNN, JOHN, JR. Civ. and Elec. Engr., 105 Maple Ave., Troy, N. Y.

FRANCISCO, FERRIS LEROY. Cons. Engr. (Francisco & Jacobs), 200 Fifth Ave., New York City.

FREDERICKSON, JOHN HENRY. Mgr., Western Office, James Stewart & Co., 320 Newhouse Bldg., Salt Lake City, Utah.

MEMBERS (*Continued*)

GARDNER, MARTIN LUTHER. Asst. Engr., P. R. R., P. R. R. Station, New York City.

GEHLER, GUSTAV WILLY. Pres., Dyckerhoff & Widmann, Kurfürstenstr. 1, Dresden, Germany.

GIDEON, ABRAHAM. Supt., Water Supply and Sewers; Cons. Engr., City Hall, Manila, Philippine Islands.

GILES, ROBERT. 59 West 45th St., New York City.

GILLETTE, HALBERT POWERS. Editor, *Engineering-Contracting*, 608 South Dearborn St., Chicago, Ill.

HANCOCK, ROBERT RIVES. Care, The Philippine Ry., Iloilo, Panay, Philippine Islands.

HANDBURY, THOMAS HENRY. Col., Corps of Engrs., U. S. A. (*Retired*); Care, American Consul-General, Dresden, Germany.

JEME, TIEN YOW. Care, Kwongtung Yueh Han Ry., Wongsha, Canton, China.

KERNOT, MAURICE EDWIN. Chf. Engr. for Ry. Constr., Railway Dept., Melbourne, Victoria, Australia.

KIMBALL, FRANK CLIFTON. Care, Commonwealth Water & Light Co., Box B, Summit, N. J.

KUTZ, CHARLES WILLAUER. Maj., Corps of Engrs., U. S. A., Manila, Philippine Islands.

KWONG, KING YANG. Imperial Peking-Kalgan Ry., Kalgan, North China.

LEA, SUMTER, JR. Room 10, Lyon Terry Bldg., Birmingham, Ala.

MCDONOUGH, CHARLES JOSEPH. Res. Engr., Barge Canal Terminals (Res., 42 Oxford Ave.), Buffalo, N. Y.

MAXIM, *Sir* HIRAM STEVENS. Sandhurst Lodge, 382 High Rd., Streatham, London, S. W., England.

MOULTON, GUY. First Res. Engr., Middle Div., New York State Canals, Drawer 46, Syracuse, N. Y.

PARKS, CHARLES WELLMAN. Civ. Engr., U. S. N.; Public Works Officer, Navy Yard, Philadelphia, Pa.

POLLOCK, CLARENCE DUBOIS. 531 East 23d St., Brooklyn, N. Y.

SELANDER, JOHN EINAR. Royal Societies Club, St. James St., London, England.

SHAND, JAMES. Cia. Constructora de Ferrocarriles, S. A., Apartado 1678, City of Mexico, D. F., Mexico.

SHANNAHAN, JOHN NEWTON. Vice-Pres. and Gen. Mgr., Newport News & Old Point Ry. & Elec. Co., Hampton, Va.

SORZANO, JULIO FEDERICO. Cons. Engr., 42 Broadway, New York City (Res., 228 Garfield Pl., Brooklyn, N. Y.).

STEVENS, JOHN FRANK. Pres., John F. Stevens Constr. Co., 55 Wall St., New York City.

STOCKETT, ALFRED WALTON. Gen. Mgr., The Simmer & Jack Proprietary Mines, Ltd., P. O. Box 5393, Johannesburg, Transvaal, South Africa.

VON PIONTKOWSKI, EDGAR STANISLAUS. Engr. in Chg., Southern Lines, Manila R. R., P. O. Box 448, Manila, Philippine Islands.

MEMBERS (*Continued*)

WARD, THOMAS MONROE. Cons. Engr., 24 Commerce St., Baltimore, Md.
WILLIAMSON, FRANCIS STUART. Care, Central R. R. Co. of Canada, 44 Beaver Hall Hill, Montreal, Que., Canada.
WILTSEE, WILLIAM PHARO. Asst. Engr., N. & W. Ry., Norfolk, Va.

ASSOCIATE MEMBERS

ALDERSON, WILLIAM HOWARD. Chf. Draftsman for Cons. Engr., Union Pacific R. R., 165 Broadway, Room 2602, New York City.
ALEXANDER, JOHN HOWARD. Eng. Contr. and Bldg. Specialties, 616 Builders Exchange Bldg., Winnipeg, Man., Canada.
ALLEN, EUGENE YORKE. Supt., Maine Slate Co., Monson, Me.
AYRES, JOHN HENRY. Asst. Engr., Office of City Engr., Manila, Philippine Islands.
BLAAUW, GEERT. Care, Panama R. R., 24 State St., New York City.
BROOKS, MILES ELIJAH. Locating Engr., Kettle River Val. Ry., Tulameen, B. C., Canada.
BROWN, ELLIOT CHIPMAN. (Elliott C. Brown Co.), Room 3050, Grand Central Terminal, New York City.
BRUNING, HENRY DIEDRICH. Acting Prof., Civ. Eng., Ohio State Univ., Lenox Hotel, Columbus, Ohio.
BURNETTE, CHAUNCEY ALLISON. Contr. Engr., Central States Bridge Co., 709 Hutton Bldg., Spokane, Wash.
BUTLER, JOHN SOULE. U. S. Asst. Engr., Lock and Dam No. 21, Palace, Ky.
CAMERON, HARRY FRANK. Div. Engr., Bureau of Public Works, and Chf. Engr., Osmeña Water-Works, Cebu, Philippine Islands.
CARTER, CLARENCE ELMORE. 19 Grand St., Reading, Mass.
COLE, OSMAN FRED. 108 Hamilton Ave., Elgin, Ill.
COLLINS, FRANK DAVID. Engr., St. Louis Plant, Am. Bridge Co., 1014 South Vandeventer, St. Louis, Mo.
COOMER, ROSS MILLER. 404 North Sheridan St., Bay City, Mich.
CORLETT, BERTRAM EDWIN. 2217½ Second St., West, Seattle, Wash.
FEDERLEIN, WALTER GOTTLIEB. Asst. Engr., Rapid Transit Subway Constr. Co., 266 West 95th St., New York City.
FOGG, PERCIVAL MORRIS. Project Engr., U. S. Reclamation Service, Rupert, Idaho.
FREY, FRANK EDWARD. Engr. and Contr., 2526 Q St., Sacramento, Cal.
GILES, ARTHUR LEONARD. Glenside, Pa.
GREEN, CHARLES NEWTON. Asst. Engr., Public Service Comm., First Dist., 154 Nassau St., Room 1916, New York City.
HAMILL, WILLIAM SAMUEL. Pres. and Gen. Mgr., William S. Hamill Co., Troy, N. Y.
HASELWOOD, FRED WILLIS. Civ. and Hydr. Engr., Willits, Cal.
HAZELTON, WILLIAM SYLVESTER. Dist. Mgr., Corrugated Bar Co., Mutual Life Bldg., Buffalo, N. Y.
HILLMAN, GEORGE WALDO. 218 Thalia St., New Orleans, La.
HOVEY, RAY PALMER. 13 Barrows Ave., Salt Lake City, Utah.

ASSOCIATE MEMBERS (*Continued*)

HOWE, WALTER CLARK. Div. Engr., Div. No. 3, California Highway Comm., Sacramento, Cal.

HUTCHINS, EDWARD. 126 Crandall St., Glens Falls, N. Y.

JONES, WALTER ALPHEUS. 19 Wall St., New Haven, Conn.

LINCOLN, LEVI BATES. Locating Engr., St. John & Quebec Ry., Woodstock, N. B., Canada.

LONG, CLARENCE BURTON. Asst. Engr., U. S. Reclamation Service, Fort Shaw, Mont.

MCNEIL, ARTHUR JAMES. Box 212, Tracy, Cal.

MAUGHMER, CARL. Chf. Asst., Div. No. 2, California Highway Comm., Redding, Cal.

MORSE, HOWARD SCOTT. Dept. of Public Service, Cincinnati, Ohio.

MOSS, ROBERT FAULKNER. Care, Am. Trading Co., Box 28, Yokohama, Japan.

MURPHY, JAMES LEO. 9 Church St., New York City.

NICHOLS, HENRY FRANCIS. 63 Grenfell St., Adelaide, South Australia.

OINOUYE, CHIKAO. Engr., Imperial Govt. Rys., Eng. Office of the Western Div., Kobe, Japan.

ORTIZ, EDUARDO. 2ª Pánuco 41, City of Mexico, D. F., Mexico.

PFEIFER, HERMAN JULIUS. Engr., M. of W., Terminal R. R. Assoc. of St. Louis, St. Louis Merchants Bridge Terminal Ry. Co., 2102 Blendon Pl., St. Louis, Mo.

PHINNEY, CASSIUS MORTON. (Phinney, Cate & Marshall), 420 Forum Bldg., Sacramento, Cal.

POND, HARRY BRADFORD. Edificio de la Mutua No. 401, City of Mexico, Mexico.

PRICE, FRANK OLIVER. Instr. in Materials and Constr., Pratt Inst., 102 Woodruff Ave., Brooklyn, N. Y.

RAIDER, HARRY ADAM. Dist. Engr., Bureau of Public Works, Manila, Philippine Islands.

REYNOLDS, LAFAYETTE CLOWE. Care, General Vehicle Co., Long Island City, N. Y.

RICHARDSON, REX DENSMORE. (Williams & Richardson), 516 Connell Bldg., Scranton, Pa.

RYAN, MICHAEL HEALEY. Care, Public Service Comm., 103 East 125th St., New York City.

SARGENT, JOSEPH ANDREWS. Chf. Engr., Insular Commercial Corporation, 43 Exchange Pl., New York City.

SARR, FRED WINTON. East Syracuse, N. Y.

SCHERMERHORN, HARVEY OBED. Res. Engr., Terminal Engr.'s Office, Lyon Blk., Albany, N. Y.

SCOTT, GUY. Div. Engr., Western Div., Penna. Lines West of Pitts., Fort Wayne, Ind.

SHAW, DAVID JOSEPH. Katonah, N. Y.

SHOEMAKER, HARRY IVES. Div. Engr., Manila Ry. Co. Ltd., Care, Manila R. R., Manila, Philippine Islands.

ASSOCIATE MEMBERS (*Continued*)

STEARNS, RALPH HAMILTON. Div. Engr., Board of Water Commrs., P. O. Drawer 54, Hartford, Conn.

STEVENS, HAROLD CONVERSE. Care, Johnson & Fuller, 150 Nassau St., New York City.

STOCKTON, JOHN. 301 Hudson St., Hoboken, N. J.

TUDBURY, WARREN CHAMBERLAIN. 8 Mall St., Salem, Mass.

TWIGGS, JOHN DAVID, JR. Engr. and Gen. Supt. of Constr., A. J. Twiggs & Son, Augusta, Ga.

WEDGEWORTH, DONALD CLARK. Res. Engr., Dept. of State Engr. and Surv., Drawer 46, Syracuse, N. Y.

WILCOX, CLARK LUZERNE. Treas., The Pitt Constr. Co., Inc., 126 Stratford Ave., Pittsburgh, Pa.

WILD, HERBERT JOSEPH. 44 Windsor Ave., Meriden, Conn.

YOUNG, LEWIS MAXWELL. Care, Connecticut Eng. & Contr. Co., Norwich, Conn.

ASSOCIATES

GILMORE, ALVIN LEROY. 207 Press Bldg., Binghamton, N. Y.

LUNDBERG, JOHN HERVID. 80 Wall St., Room 1119, New York City.

MILLER, JOHN WILLIAM. Instr., Ry. Eng., Univ. of Washington, R. F. D. No. 1, Box 136, Seattle, Wash.

JUNIORS

BALDRIDGE, JAMES RAMSEY. Contr. Engr., Hennebique Constr. Co., 1170 Broadway, New York City.

BOLTON, FRANK LEONARD. 931 Greenwood Ave., Ann Arbor, Mich.

BRONSON, HOWARD FRANKLIN. Hydrographer, Box 15, Gatun, Canal Zone, Panama.

CATER, WALTER DAY. Acting Secy., Yorktown Chemical Works, Yorktown, Va.

CORTRIGHT, EDWIN KEEN. Asst. Engr. with B. H. Davis, Cons. Engr., 215 West 23d St., New York City.

DAY, WARREN ELLIS. Box 12, Anniston, Ala.

DIMMLER, CHARLES LOUIS. 2552 Charlotte St., Kansas City, Mo.

DRIGGS, EDWIN LEROY. Asst. Engr., Bureau of Public Works, Manila, Philippine Islands.

EBERSPACHER, FRED. Box 159, Birmingham, Ala.

FARLEY, MARCUS MARTIN. Care, Board of Water Supply, High Falls, N. Y.

FEELEY, WILLIAM PATRICK. 139 West Ferry St., Buffalo, N. Y.

HARDESTY, SHORTRIDGE. Draftsman with Waddell & Harrington, 1012 Baltimore Ave., Kansas City, Mo.

HART, LAURANCE HASTINGS. Care, Lupfer & Remick, 502 Ellicott Sq. (Res., 122 Richfield Ave.), Buffalo, N. Y.

HARVEY, MICHAEL SMITH. Chf. Engr., Birmingham & Northwestern Ry., West Point, Ga.

HESS, JOHN STRIDER. Care, Duryea, Haehl & Gilman, 1315 Humboldt Bank Bldg., San Francisco, Cal.

JUNIORS (*Continued*)

HIRSCH, JOHN GEORGE. Room 42, Pearson Bldg., Madison, Wis.

HOWARD, CLEMENT JOHN. The Texas Co., Houston, Tex.

KAHN, GUSTAVE EDMUND. Chf. Engr., Sterling Eng. & Constr. Co., National Eng. & Constr. Co., Caswell Blk., Milwaukee, Wis.

McWILLIAMS, SAMUEL ALEXANDER. Care, U. S. Reclamation Service, Malta, Mont.

MALSBURY, OMER EVERT. Junior Engr., I. C. C., Culebra, Canal Zone, Panama.

MIETH, RICHARD ELAM. Mgr., Portland Bridge & Iron Co., Yeon Bldg., Portland, Ore.

MOORE, WALTER SMYTH. Asst. Engr., L. & N. R. R., Pensacola, Fla.

MURPHY, JAMES FRANCIS. Asst. Engr., Board of Water Supply, 503 West 124th St., New York City.

PARKER, KINGSBURY EASTMAN. 211 Mutual Bank Bldg., San Francisco, Cal.

SCHMID, FRANCIS RAUCH. Office of Engr. of Structures, N. Y. C. & H. R. R. R., Old Grand Central Palace, New York City.

SEGUR, ASA BERTRAND. 760 Randolph Bldg., Memphis, Tenn.

SMITH, ROBERT HALL, JR. Masonry Insp., N. & W. Ry., Box 592, Williamson, W. Va.

STANTON, ROBERT BREWSTER, JR. 125 Beacon St., Hartford, Conn.

STEESE, JAMES GORDON. First Lieut., Corps of Engrs., U. S. A., Care, Office of Chf. of Engrs., Washington, D. C.

STEWART, WALTER PHELPS. 2854 Eads Ave., St. Louis, Mo.

SWENSSON, OTTO JORDAN. Insp. with Board of Water Supply of New York City; Res., 2 Purser Pl., Yonkers, N. Y.

SWINTON, ROY STANLEY. Univ. of the Philippines, Dept. of Eng., Manila, Philippine Islands.

THAYER, NATHANIEL AUGUSTINE. 519 West 121st St., New York City.

TINGLEY, FRANCIS. 101 West Lancaster Ave., Wayne, Pa.

WALL, EDWARD WALTER. Asst. Supt., The Atlas Constr. Co., 1204 St. Lawrence Boulevard, Montreal, Que., Canada.

WILLIAMS, RECTOR LINDE. Designing and Cons. Engr., McCormack-Combs Constr. Co., Columbia Bldg., St. Louis, Mo.

YEO, WILLIAM ALBERT. Res. Engr., Chi. & Erie R. R., Markle, Ind.

RESIGNATIONS

ASSOCIATE	Date of Resignation.
STOWE, CHARLES BROWN	Mar. 5, 1912
JUNIORS	
CHACE, AMASA MANTON	Feb. 6, 1912
EWING, WILLIARD REA	Feb. 6, 1912
FEUSTEL, ROBERT MAXIMILIAN	Mar. 5, 1912
TRASK, WARREN DUDLEY	Mar. 5, 1912
WILLCOX, JAMES DEWITT	Mar. 5, 1912

DEATHS

Herron, John. Elected Member, October 4th, 1893; died February 2d, 1912.

Post, Walter A. Elected Member, March 1st, 1893; died February 11th, 1912.

Smith, T. Guilford. Elected Member, September 6th, 1871; died February 20th, 1912.

Wetherill, William Chattin. Elected Member, December 1st, 1886; died February 10th, 1912.

Total Membership of the Society, March 9th, 1912, 6 401.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(February 9th to March 8th, 1912)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1317 Spruce St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $4.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(94) *The Boiler Maker*, New York City, 10c.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., 219 Market St., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $1.50.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Mining Engrs., London, England, 6 shillings.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Southern Machinery*, Atlanta, Ga., 10c.

LIST OF ARTICLES.

Bridges.

Celio Bridge, Oregon Trunk Ry.* H. M. Harps. (87) Feb.
The St. Louis Municipal Bridge.* S. W. Bowen. (13) Feb. 8.
Cost of Concrete Highway Bridges. B. H. Piepmeier. (Abstract of paper presented to Illinois Soc. of Engrs. and Surveyors.) (13) Feb. 8.
Preliminary Studies in Bridge Design.* Reginald Ryves, Assoc. M. Inst. C. E. (104) Serial beginning Feb. 9.
New Radcliffe Viaduct on Great Northern of England.* C. Van Langendonck. (15) Feb. 9.
The Construction of the Huai River Bridge.* (14) Feb. 10.
An Electrically Operated Bascule Bridge.* Frank C. Perkins. (62) Feb. 12.
Specifications for and Cost of Replacing Wood Floors with Reinforced Concrete for Highway Bridges. Leroy C. Smith. (86) Feb. 14.
Reinforced Concrete Bridges Built Over Current River, in the City of Port Arthur, Ontario.* L. M. Jones. (96) Feb. 15.
The Saybrook Bridge on the Connecticut River.* Edward W. Bush. (Paper read before the Connecticut Soc. of Engrs.) (14) Feb. 17.

*Illustrated.

Bridges—(Continued).

Repairing the Substructure of the Bangor-Brewer Bridge. E. B. Greenwood. (14) Feb. 24.
Pneumatic Caissons at Fort William.* A. Gillies. (96) Feb. 29.
A Concrete Retaining Wall Failure.* (13) Feb. 29.
Replacing the Hancock Bridge.* (14) Mar. 2.
Waterproofing Concrete-Slab Railroad Bridges over Streets. (14) Mar. 2.
Concrete Water Barrels for Trestle Protection. Hunter McDonald. (Paper to be presented to Eng. Assoc. of the South.) (14) Mar. 2.
The Central Avenue Bridge at Rochester: A Reinforced Concrete Structure Combined with a Concrete Dam.* (14) Mar. 2.
Pont en Beton Armé, au Suquet.* James Boudet. (35) Feb.
Der Brückenbau in den letzten Jahren.* A. Rohn. (107) Jan. 27.

Electrical.

Wood and Concrete Poles in Electrical Service.* W. Monktelow. (26) Serial beginning Feb. 2.
Radio-Telegraphy.* G. W. Osborn Howe, M. I. E. E. (29) Feb. 2.
A New Electrical Ship's Telegraph Apparatus.* (26) Feb. 9.
New Power Station at Bury.* (73) Feb. 9; (26) Feb. 9.
The Distribution of Current and the Variation of Resistance in Linear Conductors of Square and Rectangular Cross-Section When Carrying Alternating Currents of High Frequency.* H. W. Edwards. (Abstract from *Physical Review.*) (73) Feb. 9.
Cost of Power Generated in Isolated Plants.* (20) Feb. 15.
Mechanical Electro-Galvanizing.* (Paper read before the National Electro-Platers' Assoc.) (20) Feb. 15.
Preservation of Power Transmission Poles. W. R. Wheaton. (Abstract of paper read before the Wood Preservers' Assoc.) (96) Feb. 15.
Electric Power in South East Kent.* (26) Feb. 16.
The Use of Batteries on Alternating Current Systems.* (12) Serial beginning Feb. 16.
Electric Power Station at Bahia Blanca.* (12) Feb. 16.
An Electric Furnace for Heating Bars and Billets. F. F. Baily. (Abstract of paper read before the Am. Electrochemical Soc.) (73) Feb. 16.
Electric Potential in Alternating Magnetic Fields.* C. F. Jenkin. (73) Serial beginning Feb. 16.
A Machine for the Calculation of Supply Networks.* J. Nowak. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Feb. 16.
Artificial Power-Transmission Line.* A. E. Kennelly and H. Tabossi. (27) Feb. 17.
Electric High-Power Tower Cranes in Foreign Harbors.* (62) Feb. 19.
The Manufacture of Telephone Cables at the Woolwich Works of Messrs. Siemens Brothers & Co., Ltd.* (73) Feb. 23.
Electrical Developments in Stratford-on-Avon.* (26) Feb. 23.
Degradation of Accumulative Energy.* A. G. Collis, A. M. I. E. E. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) Feb. 23.
Hydroelectric Station for Northern Illinois Companies.* (27) Feb. 24.
Some Problems of High-Voltage Transmissions. Charles P. Steinmetz. (42) Mar.
Characteristics of Protective Relays. E. M. Hewlett. (42) Mar.
Refractories (For Electric Furnaces). Francis A. J. FitzGerald. (105) Mar.
Operation of Two Alternating Current Stations Through Parallel Circuits, and the Distribution of Load and Wattless Currents Between Them.* J. W. Welsh. (42) Mar.
Air Gap Flux Distribution in Direct-Current Machines.* Charles R. Moore. (42) Mar.
Purity a Requisite for Silver Electroplating Anodes. J. L. R. Brown. (Paper read before the National Electroplaters' Assoc.) (105) Mar.
Industrial Electric Service in the Southern States.* A. D. Quackenbush. (27) Mar. 2.
Electrical Disturbances and the Nature of Electrical Energy. Charles P. Steinmetz. (Paper read before the Assoc. of Edison Illuminating Companies.) (19) Mar. 2.
La Station Centrale Electrique d'Eberswalde près de Berlin.* (33) Jan. 13.
Le Commutateur Téléphonique Automatique: Système Bétulander.* P. Chignaterie. (33) Feb. 10.
Telegraphenstangen aus Holz und aus Beton. F. P. W. Schröder. (80) Feb. 24.

Marine.

The Nuremberg Marine Oil-Engine.* (11) Feb. 9.
The Philadelphia Dry Dock Case: Argument before the Court of Claims on Claims for Damages for Annuling Contract. (14) Feb. 10.

*Illustrated.

Marine—(Continued).

Sea-Going Gas Driven Cargo Vessel.* (12) Feb. 16.
100-Shaft-Horse Power Diesel Marine Engine.* (11) Feb. 16.
A Further Note on Approximate Stability.* (Ships.) Arthur R. Liddell. (12) Feb. 23.
Semi-Diesel Engine on the Yacht *Mairi*.* (11) Feb. 23.
Floating Dock for Testing Submarine Boats.* (11) Feb. 23.
New Tank Steamer for the Gulf Refining Company.* (95) Mar.
Progress in Marine Engineering During the Past Fifteen Years. W. F. Durand. (95) Mar.
The First American-Built, Diesel-Engined Oil Barge.* (95) Mar.
Installations de Transbordement des Minerais de la Société Elba, à l'Ile d'Elbe.* (33) Jan. 6.
Moteur à Combustion à Deux Temps, Système Junkers.* (33) Feb. 10.
Die Verwendung von Dieselmaschinen zum Antrieb von Grösseren Seeschiffen.* W. Kaemmerer. (48) Serial beginning Jan. 20.
Entwurf zu einem Schiffshebewerk von 36m Hubhöhe.* (51) Serial beginning Feb. 14.

Mechanical.

Should Exhaust-Steam Be Wasted? P. Barrett Coulston. (Paper read before the Manchester Geol. and Min. Soc.) (106) Vol. 42, Pt. 3.
Some Recent Developments in Testing Boiler Tubes.* F. N. Speller. (89) Vol. 11.
Practice Recommended for Annealing Miscellaneous Rolled and Forged Carbon-Steel Objects. Amer. Soc. for Testing Materials. (89) Vol. 11.
A New Type of Autographic Transverse Testing Machine for Research Testing or Regular Foundry Practice. T. Y. Olsen. (89) Vol. 11.
A New Method of Testing the Indurance of Case-Hardened Gears and Pinions.* J. S. MacGregor and Bradley Stoughton. (89) Vol. 11.
A Study of Mechanical Conveyors.* Lincoln DeG. Moss. (6) Jan.
Steam Power Plants.* O. S. Lyford, Jr., and R. W. Stovel. (58) Jan.
Making Dies for Forging Machines.* J. Martin. (Abstract of paper read before the Am. Ry. Tool Foremen's Assoc.) (108) Feb.
Elements of Ball and Roller Bearing Design.* Arnold C. Koenig. (Paper read before the Soc. of Automobile Engrs.) (108) Feb.
Surface Combustion.* William A. Bone. (3) Feb.
Calculations for the Bracing of Flat Surfaces in Boilers.* J. P. Morrison. (94) Feb.
The Suckling Water-Tube Boiler.* (11) Feb. 2.
Boilers Fired with Liquid Fuel. Giulio Fumanti. (Abstract of translation of paper read before the Congresso Nazionale di Ingegnieria Navale e Meccanica.) (11) Serial beginning Feb. 2.
Mechanical Stokers at the Alexandra (Newport and South Wales) Docks and Railway.* (57) Feb. 2.
Concerning the Centrifugal Treatment of Carburetted Water-Gas Tar.* J. M. Muller. (66) Feb. 6.
Purification of Coal Gas.* J. Bridge. (Paper read before the Manchester District Junior Assoc.) (66) Feb. 6.
A Few Problems in Bituminous Suction-Gas Plants. Frank Fielden. (11) Feb. 9.
McLean's Compensated Draught Furnaces.* (11) Feb. 9.
Horizontal Compound Tandem Engine.* (11) Feb. 9.
The Leakage of Steam Past Piston Valves.* H. Denzil Lobley. (12) Feb. 9.
Plants for Sulphate of Ammonia.* C. G. Atwater. (Paper read before the Am. Gas Institute.) (24) Serial beginning Feb. 12.
Pneumatic "Springs" for Automobiles.* (13) Feb. 15.
Suburban Distribution of High Pressure Gas. H. H. Jones. (Paper read before the Convention of Managers of the H. M. Byllesby & Co.) (83) Feb. 15.
Actual Leakage in Unaccounted-for Gas.* Jacob D. von Maur. (Paper read before the Am. Gas Inst.) (83) Feb. 15.
A Large Saving of Coal.* (12) Feb. 16.
Automatic Fire Boring Machine.* (12) Feb. 16
Calorimetry. S. W. Paur. (Paper read before the Indiana Gas Assoc.) (24) Feb. 19.
The Sturtevant Steam Turbine.* (64) Feb. 20.
High-Pressure Gas in Outlying Districts.* John Kennington. (Paper read before the Junior Gas Assoc.) (66) Feb. 20.
Structure and Heat Treatment of Tool Steel.* J. V. Emmons. (Paper read before the Metal Trades Superintendents and Foremen's Club.) (20) Feb. 22.
A Few Points Concerning By-Product Coke Ovens. R. Gillon. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Feb. 23.
Large Rock-Crushing Plant for the Construction of the Kensico Dam.* Samuel W. Traylor. (14) Feb. 24; (13) Feb. 22; (103) Feb. 24; (16) Mar. 2.
The Wigglesworth Boring Mill.* (20) Feb. 29.

*Illustrated.

Mechanical—(Continued).

An African Freight Cableway.* C. A. Tupper. (13) Feb. 29.
Relative Economy of Various Types of Draft Equipment. T. F. J. Maguire. (9) Serial beginning Mar.
High-Speed Turbine Pumps.* J. W. Rogers. (10) Serial beginning Mar.
Notes on the Use of Alternating Current in Unloading Coal. W. N. Ryerson and J. B. Crane. (42) Mar.
Surface Combustion.* Raymond C. Benner. (103) Mar. 2.
Tests of Portable Vacuum Cleaners.* C. A. Pierce. (27) Mar. 2.
A Combination Lighting, Heating and Ice Plant at Louisville, Ky.* (27) Mar. 2.
The Flow of Gas in Mains.* J. W. Batten. (Paper read before the Am. Gas Inst.) (24) Serial beginning Mar. 4.
Steam Consumed by Vacuum Cleaner.* J. V. Hunter. (64) Mar. 5.
An Important Development of the Steam Engine.* Warren H. Miller. (46) Mar. 9.
Economic Aspects of the Smoke Nuisance.* John A. Switzer. (From *The Resources of Tennessee.*) (19) Mar. 9.
Aéronautique. (92) Jan.
L'Adhérence des Surfaces Planes.* H. Budgett. (Abstract of paper read before the Royal Society.) (92) Jan.
Recherches sur l'Ebullition, dans les Générateurs de Vapeur.* M. Emanaud. (33) Jan. 6.
Installations de Transbordement des Minerais de la Société Elba, à l'Ile d'Elbe.* (33) Jan. 6.
Machine à Pouiçonner et à Cisailler.* (34) Feb.
Essais sur l'Usine des Bronzes.* Portevin et Nusbaumer. (92) Feb.
Calcul des Montants et Pivots de Grues.* A. Nachtergal. (34) Serial beginning Feb.
Appareils de Manutention des Cendres dans les Usines de l'Ouest-Lumière, à Puteaux (Seine).* (33) Feb. 3.
Perfectionnement des Moteurs à Combustion Interne par le Réchauffage Préalable de l'Air.* A. Nouguier. (33) Serial beginning Feb. 24.
Betrachtungen über dynamische Zugbeanspruchung.* Rudolph Plank. (48) Serial beginning Jan. 6.
Einige Dampfkraftanlagen mit Abwärmeverwertung.* Max Hottinger. (48) Serial beginning Jan. 6.
Neuere Rohrpost- und Rohrpostmaschinenanlagen.* H. Kasten. (48) Serial beginning Jan. 13.
Versuche an einer Dreifachexpansions-Dampfmaschine.* Hubert Hanszel. (48) Serial beginning Jan. 13.
Ueber das Wesen der Flamme unserer technischen Feuerungen.* C. Dichmann. (52) Serial beginning Jan. 15.
Gegenwärtiger Stand des Formmaschinenwesens in Nordamerika.* U. Lohse. (48) Serial beginning Jan. 20.
Die Wärmemotoren an den Internationalen Industrie- und Gewerbeausstellung Turin. 1911.* P. Ostertag. (107) Serial beginning Jan. 27.
Die Elektrizität in Werkstätten für Blech- und Panzerplatten-Bearbeitung. O. Pollok. (50) Feb. 1.
Das Beförderungswesen mit aufgeladenen Fahrzeugen und Fahrzeugteilen.* Hermann R. v. Littrow. (53) Serial beginning Feb. 9.
Seil- und Kettenförderungen.* (80) Feb. 10.
Kabelbahn von Bleichert über den Surinamfluss.* (102) Feb. 15.
King-Kessel mit Zirkulationsrohr.* (107) Feb. 17.

Metallurgical.

The Transformations of Steel Within the Limits of the Temperatures Employed in Heat-Treatment.* L. Grenet. (71) Vol. 84.
The Mechanical Influence of Carbon on Alloys of Iron and Manganese.* J. O. Arnold and F. K. Knowles. (71) Vol. 84.
Temperature Influences on Carbon and Pig Iron.* E. Adamson. (71) Vol. 84.
Autogenous Welding of Metals, Oxy-Acetylene Process for Iron, Steel, and Pig Iron.* F. Carnevali. (71) Vol. 84.
The Applications of Electricity in the Metallurgical Industry of Italy. R. Catani. (71) Vol. 84.
New Industrial Processes for the Case-Hardening of Steel.* F. Giolitti. (71) Vol. 84.
On Case-Hardening by Means of Compressed Gases.* F. Giolitti and F. Carnevali. (71) Vol. 84.
The Manufacture of Pure Irons in Open-Hearth Furnaces.* A. S. Cushman. (89) Vol. 11.
Regenerative Stoves: Their Relation to Blast Furnace Practice. A. N. Diehl. (58) Jan.
Process of Autogenous Welding and Cutting of Metals. Henry Cave. (Paper read before the Am. Inst. of Steam Boiler Inspectors.) (94) Feb.

*Illustrated.

Metallurgical—(Continued).

Red Brass Ingots. H. C. Parrock. (47) Feb. 2.
Thin-Lined Blast Furnaces.* David Baker. (From *Iron Trade Review.*) (22) Feb. 2.
The Influence of Tin and Lead on the Microstructure of Brass.* F. Johnson. (Paper read before the Inst. of Metals.) (47) Feb. 9.
The Influence of Oxygen on Copper Containing Arsenic or Antimony.* R. H. Greaves. (Abstract of paper read before the Inst. of Metals.) (47) Feb. 9; (11) Feb. 9.
Problems in Modern Copper Smelting.* I. E. Bretherton. (Paper read before the Min. Assoc. of the Univ. of California.) (103) Feb. 10.
A Gravity Filter Plant.* (For Metallurgy.) C. J. Stone. (16) Feb. 17.
The Settling of Mill Slimes.* D. L. H. Forbes. (16) Feb. 24.
New Step Process for Metallizing Low Grade Iron Ores. (62) Feb. 26.
The Granby Smelter.* George M. Lee. (105) Mar.
The Important Factors in Blast Roasting.* H. B. Pulsifer. (105) Serial beginning Mar.
Concentration by Flotation of Dry Ore Pulp.* H. C. Parmelee. (105) Mar.
The Treatment of Metallic Junk.* Donald M. Liddell. (16) Mar. 2.
La Préparation de l'Acier Coulé dans le Convertisseur Stock.* (33) Jan. 6.
Etude sur les Gaz Dégagés par les Céments. H. De Nolly et L. Veyret. (92) Feb.
Ueber die Verwertung der Hochofenschlacken.* Hans Fleissner. (50) Feb. 8.
Ueber die Verwendung von Lunkerthermit bei Flusseisen-Blöcken.* C. Canaris. (50) Feb. 22.

Military.

Photographic Tests of Automatic Gun Locks.* (19) Feb. 10.
The Davis Gun-Torpedo.* (12) Feb. 23.
A Two-Company Infantry Redoubt.* L. V. Frazier. (100) Mar.
Considérations sur le Lancement des Projectiles par les Aéroplanes.* J. Olive. (33) Jan. 13.

Mining.

The Present State of the Iron Industry in Italy. L. Dompé and F. S. Pucci. (71) Vol. 84.
Reduction Control and Collection of Coal Dust in Mines. Sam Mavor, M. I. E. E. (106) Vol. 42, Pt. 3.
Surveying as Applied to Coal Mining.* William Pirie. (22) Nov. 3, 1911.
Electricity in Connection with Explosives.* E. Kilburn Scott, A. M. Inst. C. E. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) Nov. 3, 1911.
Notes on the Han-Yeh-Ping Iron and Coal Company, China.* (6) Jan.
The Electrification of the Randfontein Central. T. P. E. Butt. (Abstract of paper read before the South African Inst. of Engrs.) (22) Feb. 2.
The Sydvaranger Iron Mines.* A. Udhaugh. (22) Feb. 2.
Tube-Mill Practice and Liners.* F. C. Brown. (103) Feb. 3.
The Electric Driving of Tube Mills.* A. S. Ahrens. (From *The Electric Journal.*) (22) Feb. 9.
Stratton's Independence Mill.* T. C. Linderfelt and James K. Stewart. (16) Feb. 10.
The Rate of Burning of Fuse. Walter O. Snelling and Willard C. Cope. (Abstract from *Technical Paper No. 6*, Bureau of Mines.) (86) Feb. 14.
Driving Stone Drifts through Water-Bearing Strata. R. Watkin. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Feb. 16; (57) Feb. 9.
The Gold Mining District of Milla-Michi-Co and Malal Caballo, Territory of Neuquen, Argentine Republic. Julio Vatin and Gaston Barrie. (68) Feb. 17.
High-Duty Gravity Stamps. H. Stadler. (103) Feb. 17.
Portable Magazines for the Storage of Explosives; Methods of Thawing Dynamite.* (86) Feb. 21.
A Self-Dumping Mine-Car Haul at the Burnside Colliery, Pottsville, Pa. (13) Feb. 22; (14) Feb. 10.
Special Rules for the Installation and Use of Electricity in Mines; Issued by the Home Office of England. (22) Feb. 23.
Prevention of Coal Dust Explosions. J. Harger. (Paper read before the Soc. of Chemical Industry.) (22) Feb. 23; (57) Feb. 23.
Ore Dressing in the Joplin District.* James L. Bruce. (16) Serial beginning Feb. 24.
Mechanical Features of the California Gold-Dredge.* Robert E. Cranston. (103) Serial beginning Feb. 24; (16) Feb. 17.
Central Station Power in Coal Mines.* W. A. Thomas. (42) Mar.
Milling the Tam O'Shanter Ore.* James M. McClave. (45) Mar.
Shaft Sinking by Cement Injection.* A. L. Shrager. (Abstract of paper read before the Institution of Min. and Metallurgy.) (45) Mar.

*Illustrated.

Mining—(Continued).

Notes on Hydraulic Placer Mining.* N. A. Loggin. (Paper read before the Inst. of Min. and Metallurgy.) (45) Mar.
Limonite Prospecting and Mining.* Charlton Dixon. (45) Mar.
Electrical Control of a Large Mine Hoist.* H. W. Cheney. (42) Mar.
Electrical Symbols for Mine Maps.* H. H. Clark. (Abstract of paper read before the Coal Mining Inst. of America.) (45) Mar.
Dry-Placer Mining Methods.* Wilbur Greeley Burroughs. (45) Mar.
Longwall Mining in Illinois.* (45) Mar.
Tipple at Delagua Mine, Colorado.* A. J. Reef. (45) Mar.
Standardization in Coal Washing. Geo. R. Delamater. (45) Mar.
Mining in Mexico.* T. Lane Carter. (9) Mar.
Lessons from Recent Coal Mine Disasters. Joseph A. Holmes. (13) Mar. 7.
Compositions Destinées à Abattre et à Agglomérer les Poussières de Houille dans les Mines. (33) Feb. 24.

Miscellaneous.

Apparatus for Determining the Drop Point and Softening Point of Compounds. H. W. Fisher. (89) Vol. 11.
A Novel Method of Detecting Mineral Oil and Resin Oil in Other Oils.* A E. Outerbridge, Jr. (89) Vol. 11.
Going Value.* Frank F. Fowle. (4) Feb.
Some Observations on Retaining Walls. L. E. Conrad. (Paper read before the Kansas Eng. Soc.) (14) Feb. 17.
Library Science as an Adjunct to Engineering. Louise B. Krause. (14) Mar. 2.
An Automatic Thunder Storm Recorder.* (19) Mar. 2.
Instructions to Bidders on Contracts. Jerome Cochran. (13) Mar. 7.
The Writing of Specifications. H. P. Breitenbach. (13) Mar. 7.
Die Entwicklung des technischen Unterrichtswesens in Deutschland. Conrad Matschoss. (50) Feb. 8.

Municipal.

Report of Committee on Standard Tests for Road Materials.* (Amer. Soc. for Testing Materials.) (89) Vol. 11.
Organic Residues from Soluble Bitumen Determinations: Sulphur in Tar Residues. Prevost Hubbard and C. S. Reeve. (89) Vol. 11.
A Study of the Rattler Test for Paving Brick.* M. W. Blair and Edward Orton, Jr. (89) Vol. 11.
Improved Instruments for the Physical Testing of Bituminous Materials. Herbert Abraham. (89) Vol. 11.
A New Consistometer for Use in Testing Bituminous Road Materials.* W. W. Crosby. (89) Vol. 11.
Creosoted Wood Block Pavement with Cement Grout Filler. A. J. Schafmayer. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (14) Feb. 10.
Convict Labor on State Roads: A Report of an Experiment Carried out by Onondaga County, New York. (14) Feb. 10.
Relation of Modern Road Surfacings to Fish Life. W. J. A. Butterfield, Assoc. Inst. C. E. (Abstract of paper read before the Inst. of Mun. and County Engrs.) (66) Feb. 13; (104) Feb. 16.
Connecting Two Cities by a Roadway 100 Feet Wide Built on Marsh Land.* (14) Feb. 17.
The Use of Granite and Limestone in Highway Construction. Harry Tipper. (14) Feb. 17.
Some Cost Data on Gravel Road Construction. (86) Feb. 21.
Pipe Systems in Streets. Charles E. Bolling. (Paper read before the Am. Assoc. for the Advancement of Science.) (96) Feb. 22.
The Road: Past, Present and Future. John H. A. Macdonald, M. Inst. E. E. (Paper read before the Royal Institution.) (104) Feb. 23.
Investigations on Coal-Tar and Some of Its Products.* Arthur R. Warnes and W. B. Southerton. (Paper read before the Midland Junior Gas Assoc.) (66) Feb. 27.
Method and Cost of Constructing a Concrete Street Pavement.* Howard Egleston, M. Am. Soc. Eng. Contrs. (86) Feb. 28.
The Failure of Certain Expensive Oil Macadam Roads in Los Angeles County, California.* (86) Feb. 28.
County Road Construction in Ontario. W. A. McLean. (Paper read before the Ontario Good Roads Assoc.) (96) Feb. 29.
New Paving for Cambridge, Mass. (13) Feb. 29.
Steam Rolling of Water-Bound Macadam Roads. (96) Feb. 29.
Pneumatic Street Cleaning.* C. A. Tripp. (Paper read before the Indiana Eng. Soc.) (9) Mar.
Methods of Locating a New Highway Over Florida Mountain in the Hoosac Range in Western Massachusetts.* Andrew M. Lovis. (86) Mar. 6.
A Novel Road Machine. A. B. McDaniel. (13) Mar. 7.
Le Percement de la Rue Edouard VII sur le Boulevard des Capucines, à Paris.* A. Bidault des Chaumes. (33) Feb. 24.

*Illustrated.

Railroads.

Proposed Standard Specifications for Forged and Rolled, Forged, or Rolled Solid Steel Wheels for Engine Truck, Tender and Passenger, Subway and Elevated Railway Service. (Amer. Soc. for Testing Materials.) (89) Vol. 11.
Proposed Standard Specifications for Forged and Rolled, Forged, or Rolled Solid Steel Wheels for Freight Car Service. (Amer. Soc. for Testing Materials.) (89) Vol. 11.
Proposed Revised Standard Specifications for Locomotive Cylinders.* (Amer. Soc. for Testing Materials.) (89) Vol. 11.
Ductility in Rail Steel. P. H. Dudley. (89) Vol. 11.
Studies on Steel Tires.* Robert Job and M. L. Hersey. (89) Vol. 11.
Flue-Sheet Cinder Formation in Locomotives. Robert Job. (89) Vol. 11.
Head End Electric Train Lighting.* C. R. Gilman. (61) Jan. 16.
Railway Telephony in the United States of America. H. Marchand. (88) Feb.
Upper Quadrant Signals in Great Britain.* J. F. Gairns. (88) Feb.
The Life of Wooden and Iron Transverse Sleepers. Caner. (From *Zeitung* des Vereins deutscher Eisenbahnverwaltung.) (88) Feb.
Device for Preventing the Over-Running of Stop Signals on the Berlin Hoch- und Untergrundbahn.* M. (From *Zeitung* des Vereins deutscher Eisenbahnverwaltung.) (88) Feb.
Train Waiting at Signal Apparatus, London and North Western Railway.* (21) Feb.
Carriage and Wagon Works, Dunkinfield; Great Central Railway.* (21) Serial beginning Feb.
2-8-8-2 Engine Pennsylvania Railroad.* (21) Feb.
40-ton Centre and Side Discharging Hopper Wagon.* (21) Feb.
New Century Petrol Driven Locomotive.* (21) Feb.
Self-Propelled Cars.* W. B. Potter. (65) Feb.
Carbondale Roundhouse, D. & H. Company.* (87) Feb.
Macon Shops, Central of Georgia Ry.* (87) Feb.
Proposed Comparative Tests Between a Staybolt Firebox and a Jacobs-Shupert Sectional Firebox.* (94) Feb.
North Eastern Railway Company's New Boiler Shop.* (94) Feb.
Locomotive Weighing Machine of 160 Tons Capacity.* (11) Feb. 2.
Lötschberg Electric Locomotive No. 121.* (12) Serial beginning Feb. 2.
Steam Tractor with Condenser and Spring Draught Gear.* (12) Feb. 2.
Six-Coupled (4-6-0 Type) Passenger Locomotive, Great Eastern Railway.* (11) Feb. 9; (47) Feb. 9.
Mikado Locomotives for the Erie.* (15) Feb. 9.
The Railways' Interest in Forest Fire Prevention.* E. A. Sterling. (15) Feb. 9.
Driving the New Kingwood Railroad Tunnel at the Allegheny Summit: Double-Track Bore on Baltimore & Ohio.* E. M. Graham. (14) Feb. 10; (13) Feb. 22.
Large Coaling Station for the L. S. & M. S. Ry. near Erie, Pa.* (18) Feb. 10.
Mikado Type Locomotive for the Chesapeake & Ohio Ry.* (18) Feb. 10.
Forestry Operations on the Pennsylvania Railroad.* (96) Feb. 15.
Track Scale on the Baltimore & Ohio.* L. D. Davis. (15) Feb. 16.
The Broken Lehigh Valley Rail.* (Report of the Interstate Comm.) (15) Feb. 16.
Arrangement for Piling Ties.* J. H. Waterman. (Abstract of paper read before the Wood Preservers' Assoc.) (15) Feb. 16.
Winter Maintenance Difficulties on Northern Railways. E. R. Lewis. (15) Feb. 16.
Waterproofing Concrete Structures on C. B. & Q. Track Elevation.* G. A. Haggander. (15) Feb. 16.
Locomotives of the New York, New Haven and Hartford Railroad. (17) Feb. 17.
The Principles Governing a Railroad Appraisal of an Unusual Nature: Outline of the Views of Prof. George F. Swain on the Valuation of the New York, New Haven & Hartford Railroad. (14) Feb. 17.
Division Terminal Improvements, C. M. & St. P. Ry. at Aberdeen, S. Dak.* (18) Feb. 17.
For Improvement in the Quality of Steel Rails.* Farrell. (Paper read before the Rail Mfrs. and R. R. Presidents in New York.) (20) Feb. 22.
Pennsylvania Ore Unloading Dock at Cleveland.* (15) Feb. 23.
Tests in Smoke Abatement on Santa Fe Switching Locomotives.* (Report of Committee on Smoke Abatement and Electrification of Ry. Terminals, Chicago.) (15) Feb. 23.
Experiments on Fire-Boxes, Tubes, and Stays.* Robert Weatherburn. (12) Serial beginning Feb. 23.
The Balancing of Locomotives.* Jas. Dunlop. (47) Serial beginning Feb. 23.
Pneumatic Sleet Shoe Used by Michigan United Railways.* (17) Feb. 24.
Standard Designs in Concrete Track Structures, Baltimore and Ohio Railway.* (86) Feb. 28.
The Operation of Steam Railroads by Electric Motors.* J. B. Whitehead. (10) Mar.

---

*Illustrated.

Railroads—(Continued).

The Electrification of Steam Railways.* Arthur Curran. (10) Mar.
To Sea By Rail.* M. B. Claussen. (10) Mar.
The Question of the Improvement of Rail Design and Specifications. W. C. Cushing. (Paper read before the Indiana R. R. Comm.) (15) Mar. 1.
Experimental Mallet Locomotive for the Pennsylvania.* (15) Mar. 1.
Construction of the Milwaukee, Sparta & Northwestern.* (15) Mar. 1.
The Problem of the Railway Rail.* Robert G. Skerrett. (19) Mar. 2.
Postal Cars for the Missouri Pacific Ry.* (18) Mar. 2.
The Street Locomotive Stoker.* (18) Mar. 2.
Methods of Making Culvert Extensions in Widening Roadbed, New York Central & Hudson River R. R.* Charles E. Anderson. (86) Mar. 6.
An Improved Locomotive Firebox.* (13) Mar. 7.
Location of Frog Points on Crandall's Transition Curves.* Anders Bull. (13) Mar. 7.
A Large Railway Ferry Steamer for the Volga.* F. C. Coleman. (19) Mar. 9.
Locomotives Compound Mallet du Southern Pacific Railway.* (33) Jan. 6.
Basculeurs et Culbuteurs pour le Déchargement des Vagons.* (34) Feb.
Appareil de Changement de Marche Système Ch. Roisin, à Vapeur ou à Air Comprimé, pour Locomotives.* L. Pierre-Guédon. (33) Feb. 3.
Locomotive Electrique à Redresseur-Régulateur Alternatif-Continu de MM. Auvert et Ferrand.* A. Bidault des Chaumes. (33) Feb. 17.
Le Réchauffage de l'Eau d'Alimentation et la Condensation de la Vapeur d'Echappement dans les Locomotives et Automotrices.* (33) Feb. 17.
Uebersicht über die Verfahren zur Reinigung und Entseuchung der Eisenbahn-Personenwagen. J. Dohnal. (102) Feb. 1.
Der Verschiebe- und Umlade-Bahnhof Kalk-Nord.* Baumgarten. (102) Serial beginning Feb. 1.
Ueber den Lauf steifachsiger Fahrzeuge durch Bahnkrümmungen.* Karl Schloss. (102) Serial beginning Feb. 1.
Die Berninabahn.* E. Bosshard. (107) Serial beginning Feb. 10.
Erfahrungen beim Verlegen von Zahnstangenoberbau, Ruegenberg. (102) Serial beginning Feb. 15.
Neue elektrische Bahnen der Schweiz.* P. Poschenrieder. (53) Serial beginning Feb. 23.

Railroads, Street.

The New Sand-Drying Plant of the United Railways Company of St. Louis.* C. L. Hawkins. (Paper read before the Engrs.' Club of St. Louis.) (1) Feb.
Tirrill Regulator; The Mersey Electric Railway.* (11) Feb. 2.
Forbes Street Terminal of the Pittsburg Railways.* (17) Feb. 10.
Plant of Capital Traction Company.* J. H. Beattie. (64) Feb. 13.
Brooklyn Rapid Transit Line Specifications.* (17) Feb. 17.
Cost of Concrete Abutments and Pedestals on Track Elevation Work Where Lack of Room Made Construction Difficult.* Charles G. Huestis (86) Feb. 21.
New Hydro-electric Station of the Northern Illinois Light and Traction Company at Marseilles, Ill.* (17) Feb. 24.
Subway Equipment Improvements.* (13) Feb. 29.
South Boston Power Station of Boston Elevated Railway.* (17) Mar. 2.
Tunneling Under the Brooklyn Subway. (14) Mar. 2.
New Car for Memphis, Tenn.* (17) Mar. 2.
Transit Developments in London, England. H. Raynor Wilson. (13) Mar. 7.

Sanitation.

Standard Tests for Drain Tile and Sewer Pipe.* A. Marston. (89) Vol. 11.
Schedule for Analytical Data for Sewer Pipe: Demands and Properties; Mill, Field and Laboratory Tests. (Amer. Soc. for Testing Materials.) (89) Vol. 11.
Disposal of City Wastes.* Pell W. Foster. (6) Jan., 1911.
Flush-Tank Siphons.* S. Fischer Miller. (98) Jan.
Main Drainage Works, Toronto, Canada.* R. C. D. Tempest. (36) Feb.
Batavia, N. Y., Sanitary Sewer System.* R. L. Fox. (36) Feb.
Sanitary Regulations Governing Construction Camps. Jerome Cochran. (36) Feb.
Imhoff Tanks at Madison-Chatham, N. J.* Clyde Potts. (36) Feb.
A Brief Sketch of the Havana (Cuba) Sewer and Drainage System.* H. E. Hyde, M. Am. Soc. C. E. (36) Feb.
Drainage Improvements and Intercepting Sewer System for Syracuse, N. Y.* Stephen B. Vernon, Assoc. M. Am. Soc. C. E. (36) Feb.
Lethbridge, Alberta, Sewage Disposal Works.* T. Aird Murray, M. Can. Soc. C. E. (104) Feb. 2.
The Destruction of House Refuse by Incineration. Ray R. Knight, A. M. Can. Soc. C. E. (96) Feb. 8.
Pollution of the River Tarne.* John D. Watson. (13) Feb. 8.
The Influence of Ozone in Ventilation. Leonard Hill and Martin Flack. (29) Feb. 9.

*Illustrated.

Sanitation—(Continued).

A Sewer Outlet Under a Pier.* (14) Feb. 10.
Construction and Maintenance of Open Drainage Ditches. G. P. Smith. (Paper read before the Iowa Eng. Soc.) (14) Feb. 10.
The Design of the Sewage Disposal Plant at Winchester, Kentucky.* Charles E. Collins. (86) Feb. 14; (14) Mar. 2.
The Use of an Inverted Siphon in Street Drainage.* L. E. Curfman. (Paper read before the Kansas Eng. Soc.) (86) Feb. 14.
An Outgrown Sewage Purification Plant at Madison, Wis. James Mackin. (13) Feb. 15.
Heating a Twelve-Story Loft Building.* (101) Feb. 16.
Septic Tank System of Waste Disposal. F. W. Tower. (Paper read before the New England Plumbing Inspectors' Assoc.) (101) Feb. 16.
A Method of Waterproofing Sewers Successfully Employed at South Orange, N. J. Eardley C. Cattley. (86) Feb. 21.
Refuse Disposal, Toronto, Ont. (13) Feb. 22.
Protection of Trap Seals.* W. A. M. (101) Serial beginning Feb. 23.
The Sewage Disposal Works at Baltimore.* (14) Feb. 24.
The Susquehanna River Intercepting Sewer (Harrisburg, Pa.).* (14) Feb. 24.
Under-Drainage of Alluvial Lands. J. A. Harman, M. Am. Soc. C. E. (Paper read before the Assoc. of Drainage and Sewer Districts of Illinois.) (14) Feb. 24.
The Most Important Sewerage and Sewage Disposal Report Made in the United States (Pittsburgh). (14) Feb. 24; (13) Feb. 29.
Steam Heating Large Department Stores.* Davis S. Boyden. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (64) Feb. 27.
Gas From Sewage Sludge. J. Grossman. (Paper read before the Soc. of Chemical Industry.) (66) Feb. 27.
Cost of Trenching with Sewer Excavator in Moundsville, W. Va. A. W. Peters. (86) Feb. 28.
The New Public Health. H. W. Hill. (From the *Minnesota Journal Lancet.*) (13) Feb. 29.
A Study of the Various Influences on the Rate of Transmission with Fan Coil Heaters.* Frank L. Busey. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (70) Mar.
Heating and Ventilating Hotel Kimball, Springfield, Mass.* (70) Mar.
Provisions of Chicago New Ventilation Law. Chicago City Council. (101) Mar. 1.
House Heating Systems of Russia.* Arthur C. Peters. (101) Mar. 1.
Plumbing in a Municipal Laundry and Bath.* (101) Mar. 1.
Cabinets d'Aisances Publics de la Ville de Milan.* (35) Feb.

Structural.

Destruction of Cement Mortars and Concrete Through Expansion and Contraction.* A. H. White. (89) Vol. 11.
The Expansion and Contraction of Concrete While Hardening.* A. T. Goldbeck. (89) Vol. 11.
Some Experiments on the Incrustation and Absorption of Concrete. A. O. Anderson. (89) Vol. 11.
Standard Specifications for Heat-Treated Carbon-Steel Axles, Shafts and Similar Parts.* Amer. Soc. for Testing Materials. (89) Vol. 11.
Standard Specifications for Steel Reinforcement Bars. Amer. Soc for Testing Materials. (89) Vol. 11.
Strength of Steel from Structural Shapes.* E. L. Hancock. (89) Vol. 11.
A Study of the Elastic Properties of a Series of Iron-Carbon Alloys.* C. R. Jones and C. W. Waggoner. (89) Vol. 11.
Life History of Network and Ferrite Grains in Carbon Steel.* H. M. Howe. (89) Vol. 11.
The Behavior of Cast Zinc Under Compression.* J. C. Trautwine, Jr. (89) Vol. 11.
Report of Committee on the Corrosion of Iron and Steel. Amer. Soc. for Testing Materials. (89) Vol. 11.
Report of Committee on the Tempering and Testing of Steel Springs and Standard Specifications for Spring Steel.* Amer. Soc. for Testing Materials. (89) Vol. 11.
Report of Committee on Standard Specifications for Hard-Drawn Copper Wire.* Amer. Soc for Testing Materials. (89) Vol. 11.
Report of Committee on Waterproofing Materials. Amer. Soc. for Testing Materials. (89) Vol. 11.
Standard Methods for Transverse Tests of Metals. Amer. Soc. for Testing Materials. (89) Vol. 11.
Report of Committee on Preservative Coatings for Structural Materials. Amer. Soc. for Testing Materials. (89) Vol. 11.
New Types of Impact Testing Machines for Determining Fragility of Metals.* T. T. Olsen. (89) Vol. 11.

*Illustrated.

Structural—(**Continued**).

The Heat Treatment of a Steel Containing 3.15 Per Cent. Nickel and 0.27 Per Cent. Carbon.* William Campbell and H. B. Allen. (89) Vol. 11.
Some Causes of Failures in Metals.* Henry Fay. (89) Vol. 11.
The Heat Treatment of an Acid and a Basic Open Hearth Steel of Similar Composition. Henry Fay. (89) Vol. 11.
Study of the Heat Treatment of Some Low-Carbon Nickel Steels.* Henry Fay and J. M. Bierer. (89) Vol. 11.
The Fritz Engineering Laboratory of Lehigh University.* F. P. McKibben. (89) Vol. 11.
Practical Tests of Sand and Gravel Proposed for Use in Concrete. R. S. Greenman. (89) Vol. 11.
The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete.* R. J. Wig. (89) Vol. 11; (86) Feb. 28.
Report of Committee on Standard Specifications for Steel. Amer. Soc. for Testing Materials. (89) Vol. 11.
Standard Specifications for Copper-Wire Bars, Cakes, Slabs, Billets, Ingots, and Ingot Bars. Amer. Soc. for Testing Materials. (89). Vol. 11.
Standard Specifications for Spelter. Amer. Soc. for Testing Materials. (89) Vol. 11.
Standard Specifications for Manganese Bronze Ingots.* Amer. Soc. for Testing Materials. (89) Vol. 11.
The Determination of Stresses in a Reinforced Concrete Member Subject to Axial Load and Flexure.* S. Ingberg. (89) Vol. 11.
A Comparison of Five Methods of Hardness Measurement.* R. P. Devries. (89) Vol. 11.
Hardness in Its Relation to Other Physical Properties.* R. P. Devries. (89) Vol. 11.
The Property of Hardness in Metals and Materials.* A. F. Shore. (89) Vol. 11.
Specifications and Grading Rules for Douglas Fir Timber: An Analysis of Forest Service Tests on Structural Timbers.* McGarvey Cline. (89) Vol. 11.
Some Further Experiments Upon the Absorption, Porosity and Specific Gravity of Building Bricks. D. E. Douty and L. L. Beebe. (89) Vol. 11.
The Value of the Sulphuric Acid Corrosion Test.* C. M. Chapman. (89) Vol. 11.
The Marked Influence of Copper in Iron and Steel on the Acid Corrosion Test. W. H. Walker. (89) Vol. 11.
Some Tests on the Rate of Corrosion of Metals Exposed to Locomotive Gases. A. W. Carpenter. (89) Vol. 11.
Further Results of the Westinghouse, Church, Kerr and Company Paint Tests. C. M. Chapman. (89) Vol. 11.
The Practical Testing of Drying and Semi-Drying Paint Oils.* H. A. Gardner. (89) Vol. 11.
Notes on Computations in Building Construction in New York City. J. K. Finch. (Paper read before the Columbia Univ. Civ. Eng. Soc.) (6) Jan., 1911.
The General Theory of Elastic Arch Ribs According to the Law of Least Work. Wm. H. Burr. (6) Jan.
Notes on Structural Steel Designs.* Albert Reichmann. (4) Feb.
Consistency of Concrete. (Report of the Committee of the Concrete Institute.) (96) Feb.
Micrographic Examination of Failures.* J. S. Glen Primrose. (Abstract of paper read before the Glasgow Univ. Eng. Soc.) (96) Feb.
Creosote Oil, Specifications and Methods of Analysis. S. R. Church. (Paper read before the Wood Preservers' Assoc.) (87) Feb.
Evaporation of Creosote and Crude Oils. P. E. Fredendoll. (Paper read before the Wood Preservers' Assoc.) (87) Feb.; (18) Feb. 17.
The Bessemer Laboratory, Royal School of Mines.* (12) Feb. 2.
Steel-Sheet Piling for Cofferdams.* (11) Feb. 2.
Settlement and Reinforcement of the Unity Building, Chicago. (13) Feb. 8.
Proposed Specifications for Hollow Clay Tile Building Blocks.* Virgil G. Marani. (13) Feb. 8.
Strength Values for Structural Timbers. McGarvey Cline. (From *Circular 189*, U. S. Forest Service.) (96) Feb. 8.
Proposed New Solder Specifications. H. J. Skinner. (Paper read before the Am. Chemical Assoc.) (101) Feb. 9.
Block v. Cottage Dwellings. E. C. P. Monson. (Paper read before the Soc. of Architects.) (104) Feb. 9.
The Substructure of the New Daniels & Fisher Stores at Denver.* (14) Feb. 10.
A Discussion of the Economics of Practical Concrete Construction.* DeWitt V. Moore. (Paper read before the Indiana Eng. Soc.) (86) Feb. 14.
Methods and Costs of Proportioning Gravel Concrete.* Clifford Older. (Abstract of paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) Feb. 14.
Discolorations on Brick. Charles F. Binns. (76) Feb. 15.
Recognizing Alloy Steels by Ingot Structure.* E. T. Edwards. (20) Feb. 15.
The Steel Substructure of the Woolworth Building in New York City.* (14) Feb. 17.

*Illustrated.

Structural—(Continued).

Underpinning an Electric-Light Substation.* (14) Feb. 17.
Inspection of Forms and Centering (Concrete Work). Jerome Cochran. (86) Feb. 21.
Strength Values for Structural Timbers. (13) Feb. 22.
The Zinn Building.* T. Kennard Thomson, M. Am. Soc. C. E. (96) Feb. 22.
Submerged Concrete Work.* (96) Feb. 22.
The Hydraulic and Mechanical Laboratories of the University of Toronto, Toronto, Canada.* Robert W. Angus. (11) Serial beginning Feb. 23.
Cylinder Foundation in Ferro-Concrete.* (11) Feb. 23.
Hospitals and Sanatoria. Alban H. Scott. (Abstract of paper read before the Inst. of San. Engrs.) (104) Feb. 23.
Wind Bracing in the Woolworth Building.* (14) Feb. 24.
Tests on Flat Slab Floors.* (14) Feb. 24.
An English Proposed System of Forms for Building Construction.* H. Kempton Dyson. (Abstract from *Concrete and Constructional Engineering.*) (86) Feb. 28.
Inspection of Steel Reinforcements. Jerome Cochran. (86) Feb. 28.
New Tests on Reinforced-Concrete Columns at the University of Wisconsin. (13) Feb. 29.
Permanent Structures. James S. Bell. (Paper read before the Ontario Good Roads Assoc.) (96) Feb. 29.
Manganese Extensively Used in Brick Manufacture for Producing the Popular Brown, Grey, and Mottled Effects. Ellis Lovejoy. (76) Mar. 1.
The Collapse of the Spang-Chalfont Building (Reinforced Concrete).* (13) Feb. 29; (14) Mar. 2; (62) Mar. 4.
Heavy Power-House Foundations.* (14) Mar. 2.
General Conclusions Based on Results of Tests on Reinforced Concrete Columns.* (86) Mar. 6.
Inspection of Concreting. Jerome Cochran. (86) Mar. 6.
Die Schubbewehrung der Eisenbetonbalken. R. Saliger. (51) Sup. No. 4.
Prüfung feuerfester Steine. M. Gary. (48) Jan. 6.
Versuche mit umschnürtem Gusseisen.* v. Emperger. (78) Serial beginning Feb. 2.
Balkenversuche.* Fritz von Emperger. (78) Feb. 2.
Die Universitäts-Frauenkliniken des neuen Wiener k. k. Allgemeinen Krankenhauses.* Robert Jaksch. (53) Feb. 2.
Regeln für die Verbundanordnung (Haftfestigkeit) von Eisenbetonbalken.* F. v. Emperger. (53) Feb. 9.
Die Folgen des Gebrauchs unrichtig zusammengesetzter Mörtel. Joannini. (80) Feb. 15.
Höhenänderung gemauerter Pfeiler infolge Erhärtung des Mörtels. Karl Scheel. (78) Feb. 17.
Eisen-Konstruktionen des Geschäftshauses Ecke Königgrätzer- und Köthener-Strasse in Berlin.* O. Leitholf. (51) Serial beginning Feb. 21.
Prüfung und Eigenschaften holländischer Ziegel und Kalksandsteine. B. Krieger. (80) Feb. 22.
Die Magdalenkirche in Strassburg i. Els.* E. Conrad. (78) Feb. 26.
Betonkonstruktionen der unterirdischen Bedürfnisanstalten in Charlottenburg.* Zangemeister. (78) Feb. 26.
Die neuen Speicheranlagen auf dem Holm in Danzig.* R. Kohnke. (78) Serial beginning Feb. 26.
Zur Berechnung der Verbundsäulen. O. Domke. (78) Feb. 26.
Das Eisenbetondach des Städtischen Speichers am Osthafen in Berlin.* (78) Feb. 26.
Der neue Hauptbahnhof in Leipzig.* A. Kleinlogel. (78) Serial beginning Feb. 26.
Die Eisenbetonkonstruktionen der Grossmarkthalle in München.* B. Rueb und A. Keller. (78) Feb. 26.
Vom Mauerwerks-Gewichte.* E. Suenson. (80) Feb. 27.
Gebäudesetzungen.* K. Böhm-Gera. (80) Feb. 27.

Topographical.

A Photogrammetric Gun for Making Surveys in a Balloon.* (46) Feb. 10.
Making Practical Use of the U. S. Primary Triangulation System. William Bowie. (13) Feb. 22.

Water Supply.

The Concrete Dam in Freeman's Run, Austin, Pa.* Frank P. McKibben. (98) Jan.
The Use of the Great Lakes.* Robert R. McCormick. (4) Feb.
The Syphon.* Joseph Parker. (Paper read before the National Assoc. of Colliery Managers.) (22) Feb. 2.

*Illustrated.

Water Supply—(Continued).

Automatic Water Supply Booster.* C. A. Tupper. (13) Feb. 8.
Irrigation in South Africa.* W A. Legg, M. Inst. C. E. (29) Feb. 9.
Developing Electrical Energy from the Los Angeles Aqueduct.* Howard S. Knowlton. (27) Feb 10.
Operation Results of the Slow Sand Filters at Indianapolis. (14) Feb. 10.
Laying a 30-Inch Submerged Intake Pipe at Ogdensburg.* (14) Feb. 10.
Water-Pressure Reducing and Regulating Device.* S. Whinery. (14) Feb. 10.
The Power Plants of the Southern Indiana Power Co.* DeWitt V. Moore. (Paper read before the Indiana Eng. Soc.) (14) Feb. 10.
Two 4 000 000-Gallon Circular Reinforced Concrete Reservoirs at Brockton.* (14) Feb. 10.
Properties of the Air Lift Pump—Its Advantages and Disadvantages.* G. J. Davis and C. R. Weidner. (Abstract from *Bulletin No. 450*, Univ. of Wisconsin.) (86) Feb. 14.
Irrigation Management. F. W. Hanna. (13) Feb. 15.
Special Venturi Meters at the Wachusett Dam.* E. R. B. Allardice and F. N. Connet. (13) Feb. 15.
An Automatic Dam Crest.* G. F. Stickney. (13) Feb. 15.
Improved Sand-Washer.* (12) Feb. 16.
Hydro-electric Plant of North Carolina Electrical Power Co.* N. Buckner. (27) Feb. 17.
New Hydro-electric Plant at Asheville, N. C.* N. Buckner. (19) Feb. 17.
Failure of a Low Concrete Dam near Shippensburg, Pennsylvania.* Charles E. Ryder. (14) Feb. 17.
The Snell Hydro-Electric Development on Raquette River, New York.* (14) Feb. 17.
Water Power Development in Ohio.* E. F. Baker. (64) Feb. 20.
Water-Works Extension in Kansas City, Kansas, Details of Design.* (86) Feb. 21.
An Efficient Cheap Dam.* H. D. Mendenhall. (13) Feb. 22.
Large Rock-Crushing Plant for the Construction of the Kensico Dam.* Samuel W. Traylor. (14) Feb. 24; (13) (Feb. 22); (103) Feb. 24; (16) Mar. 2.
The Hydro-Electric Plant at Marseilles, Ill.* (14) Feb. 24.
California Evaporation Records. Edwin Duryea, Jr. (13) Feb. 29.
Steel Siphons for New York's Water Supply.* (20) Feb. 29.
Dam Inspection in Pennsylvania. Farley Gannett. (13) Feb. 29.
Failure of a Log and Earth Fill Dam at Union Bay, B. C.* A. K. Mitchell. (13) Feb. 29.
New Settling Basin of the Water-Works at Kansas City.* Wynkoop Kiersted. (13) Feb. 29.
Water Supply of the District of Columbia.* Warren T. Hannum. (100) Mar.
Wells and Well Pumping Machinery.* Charles Brossman. (Abstract of paper read before the Indiana Eng. Soc.) (9) Mar.
The Chloride Process for Water Purification. W. H. Bull. (Paper read before the Indiana Sanitary and Water Supply Assoc.) (9) Mar.
Notable Work on the Catskill Aqueduct.* (9) Mar.; (96) Feb. 29.
Navigation Companies vs. Water Power Users, Sebago Lake, Maine.* Lewis M. Adams. (101) Mar.
Electricity on Catskill Aqueduct for New York City Water Supply.* (27) Mar. 2.
An Effective Type of Expansion Joint for Concrete (Reinforced Concrete Flume).* (14) Mar. 2.
A Municipal Hydro-Electric Plant; Replacing Steam by Water Power in the City of Sturgis, Michigan.* Louis E. Ayres. (14) Mar. 2.
A Compressed Air Grouting Machine for Grouting Tunnel Lining.* (86) Mar. 6.
Some Operating Costs of Power Plants and Pumping Stations. Dabney H. Maury. (Report to the Chicago Water-Works Comm.) (86) Mar. 2.
Hypochlorite Plant, Cleveland, Ohio. C. F. Schulz. (13) Mar. 7.
Les Grands Travaux d'Irrigation des Etats-Unis: Barrage-Réservoir Roosevelt.* (33) Serial beginning Feb. 3.

Waterways.

A Sandy Belt on the Madras Coast.* Reginald Ryves. (12) Feb. 2.
Liverpool Dock Extensions.* (12) Serial beginning Feb. 9.
A Reinforced-Concrete Ore Dock.* (14) Feb. 10.
Methods of Channel Protection with a Description and Costs of a Special Method Employed at Devil's Island, Illinois.* F. Y. Parker. (86) Feb. 14.
Water Supply Projects in Connection with the New York State Barge Canal.* W. G. Wildes. (13) Feb. 15.
A Comparison of Four Methods of Making Soundings.* Myron H. Peck. (13) Feb. 22.

*Illustrated.

Waterways—(Continued.)

A Large Railroad Ore Dock of Concrete Construction at Cleveland.* (14) Feb. 24; (13) Feb. 22.
Unit Costs of Work in the Panama Canal for the Fourth Quarter of 1911.* (86) Feb. 28.
Land Reclamation by Flood Protection; a Typical Problem and Its Solution.* (86) Feb. 28.
Dredges and Dredging in the Mobile District.* J. M. Pratt. (100) Mar.
Accidents and Damages to Vessels on the Great Lakes and Connecting Channels, 1901-1910.* John Millis. (100) Mar.
Regulation of the Hiwassee River Near Charleston, Tenn.* Nicholas W. Bowden. (100) Mar.
Guard Locks in Canals Connecting Tidal Bodies of Water.* Earl I. Brown. (100) Mar.
Harbour Dredging.* Brysson Cunningham. (10) Mar.
Navigation Companies *vs.* Water Power Users, Sebago Lake, Maine.* Lewis W. Adams. (100) Mar.
The Construction of Cofferdams. (14) Mar. 2.
The Operation of the Locks of the Panama Canal.* (14) Mar. 2.
Revetment Construction for a Railroad Bridge over the Missouri River; Method of Placing a Willow Mat and Account of Its Service against Erosion.* A. A. Schenck. (14) Mar. 2.
A Reinforced Concrete Dock in New York Harbor. (14) Mar. 2.
A Forty-Ton Floating Derrick.* (14) Mar. 2.
Methods and Cost of Constructing Lock No. 6 and Guard Gate, New York State Barge Canal.* E. J. Becker. (86) Mar. 6.
The Floating Caisson for Gatun Spillway Dam.* Edward C. Sherman. (13) Mar. 7.
Land-Side and River-Side Levee Borrow Pits and the Principles of Earthwork Drainage. Wm. L. Marshall. (13) Mar. 7.
The New South Brooklyn Freight Terminal, New York Harbor.* Charles W. Staniford and Philip Guise. (13) Mar. 7.
Dock Flottant pour l'Immersion de Caissons-Blocs en Béton Armé du Port de Kobé (Japan). Alexandre Delisle. (13) Jan. 13.
Commande Hydraulique des Portes d'Une Ecluse: Système Nyholm.* (33) Feb. 17.
Die Schleusentore des Industrie- und Handelshafens zu Bremen-Oslebshausen.* Ernst Overbeck. (48) Jan. 6.
Automatisch bewegliche Wehrklappe.* H. Oostinjer. (107) Feb. 10.

---

*Illustrated.

Vol. XXXVIII. MARCH, 1912. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

CONTENTS

PLATES

For Index to all Papers, the discussion of which is current in *Proceedings*, see the end of this number.

Vol. XXXVIII. MARCH, 1912. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A FOUR-TRACK, CENTER-BEARING, RAILROAD DRAW SPAN.

By Louis H. Shoemaker, M. Am. Soc. C. E.

To be Presented April 3d, 1912.

The four-track draw span recently completed for the Bessemer and Lake Erie Railroad at Conneaut Harbor, Ohio, is of interest mainly on account of the special type of construction necessitated by the extremely limited height from base of rail to masonry. It is somewhat unusual to be required to support a draw span 235 ft. long and 67 ft. wide, with a turning load of nearly 1 400 tons, in a depth of 5 ft. 8 in. Moreover, the frequent high-water stage made it necessary to limit the depth of the floor system to 3 ft. 3 in. from base of rail to underclearance.

To conform to these conditions, in a bridge designed for Cooper's *E*-60 engine loading, necessitated short panels and floor-beams of single track length. A radical departure from standard types of construction was evidently necessary. The unusual width of the structure, together with the limited height available for the drum and the distributing girders, evidently excluded from consideration the rim-bearing type of center. It was evident, also, that the practicability

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

of using the center-bearing type depended on the adoption of a design which would reduce the length of the center supporting girders to a minimum.

The general features of the design adopted to meet these conditions are as follows:

There are two main trusses of unusual depth, 32 ft. 7 in. apart from center to center. Two tracks are supported between the trusses and two on overhangs outside. The trusses are of the sub-divided Warren type, with 14 ft. 8¼-in. panels. Deep overhead transverse trusses at the main panel points, with cantilever extensions, support the floor system by three lines of hangers. At the sub-panel points the floor system is supported from three lines of longitudinal trusses, one line overhead on the center line of bridge and two lines on the outside, which in turn are supported by the transverse trusses. There are two pairs of center supporting girders, the ends of each pair being connected by short girders, which support the main trusses, distributing the dead load from the main trusses to the transverse supporting girders, and also transmitting the live load from the main trusses through the center wedges to the masonry. The main carrying girders are supported by eight 12 by 1⅞-in. eye-bars from a short longitudinal double-web girder which is supported on the center.

The bridge turns on a 34-in. phosphor-bronze disc acting between two nickel-steel discs. The pressure on these discs is about 3 500 lb. per sq. in. There are four end and two center wedges, and the power for operating them is transmitted by a longitudinal shaft, on the center line of the bridge, placed several feet above the track level and supported on the center suspenders. All wedges are driven transversely to the center line of the bridge.

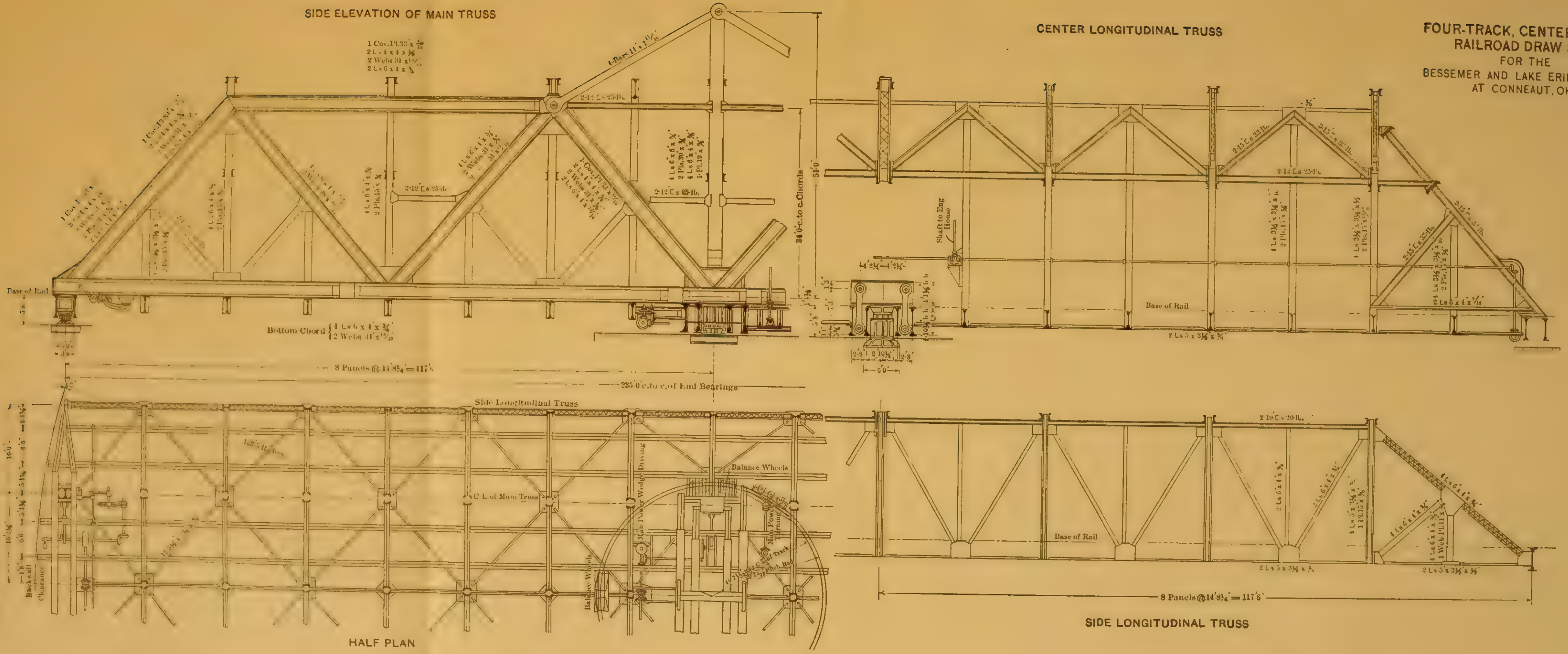
The turning operation is performed by two pairs of pinions connected by equalizers acting on a rack having a pitch diameter of 41 ft. $2\frac{3}{16}$ in. The ends of the bridge are fitted with rail locks. Figs. 1 and 2 and Plate XIII show the general construction and the arrangement of the machinery in detail. As it is not necessary to turn the bridge at present, the motive power has not yet been installed.

The views on Plate XIV were taken during a loading test of the bridge. Fig. 1 shows one overhang loaded with heavy freight engines, the average weight being 6 100 lb. per lin. ft. of track. The maximum deflections observed were entirely satisfactory.

PLATE XIII.
PAPERS, AM. SOC. C. E.
MARCH, 1912.
SHOEMAKER ON
RAILROAD DRAW SPAN.

FOUR-TRACK, CENTER-BEARING RAILROAD DRAW SPAN

FOR THE
BESSEMER AND LAKE ERIE RAILROAD
AT CONNEAUT, OHIO.



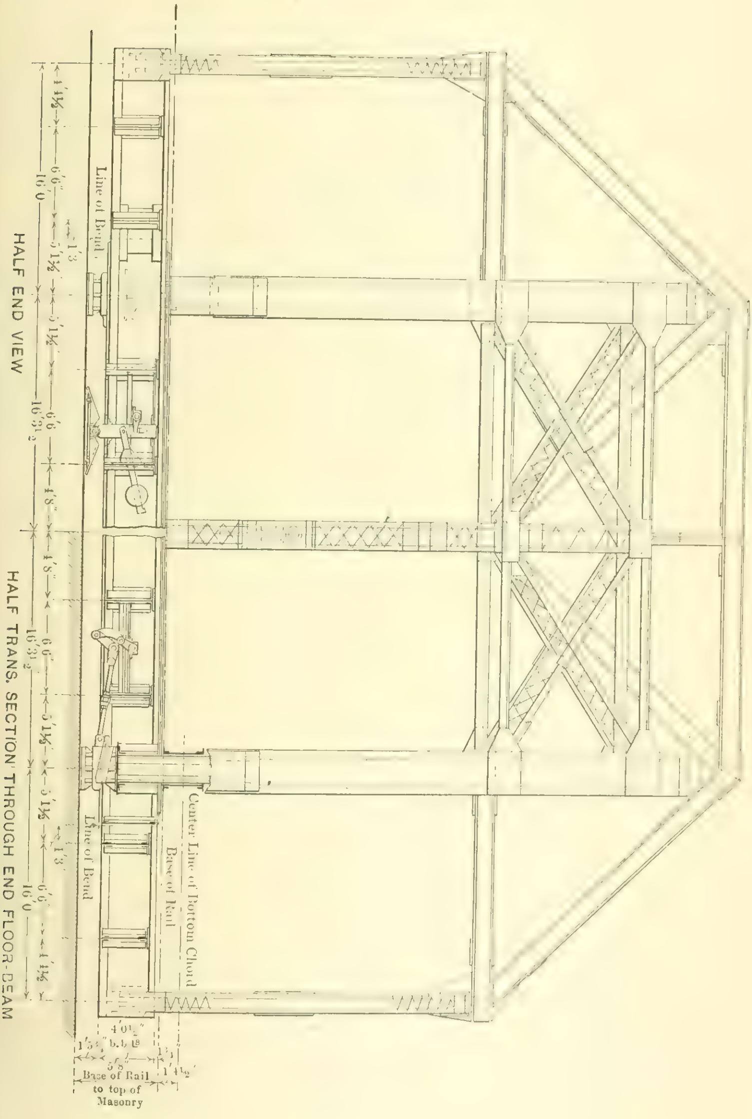
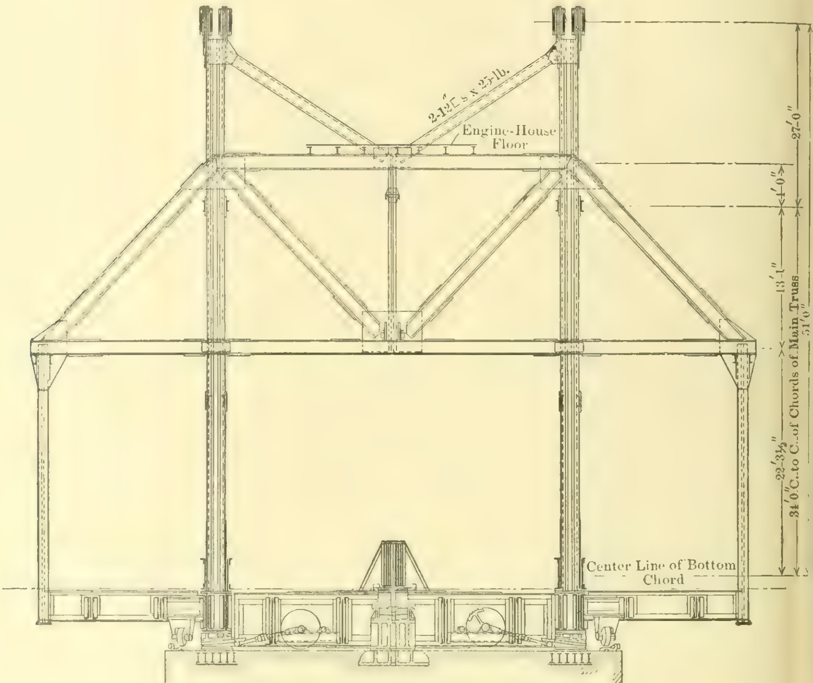
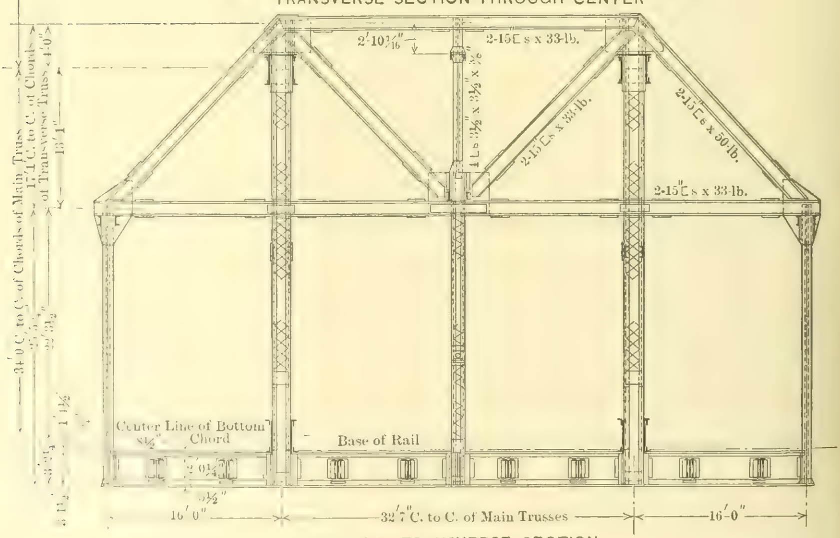

HALF END VIEW
HALF TRANS. SECTION THROUGH END FLOOR-BEAM
Line of Bend
Line of Bend
Center Line of Bottom Chord
Base of Rail
Base of Rail to top of Masonry

Fig. 1.



TRANSVERSE SECTION THROUGH CENTER



TYPICAL TRANSVERSE SECTION

FIG. 2.

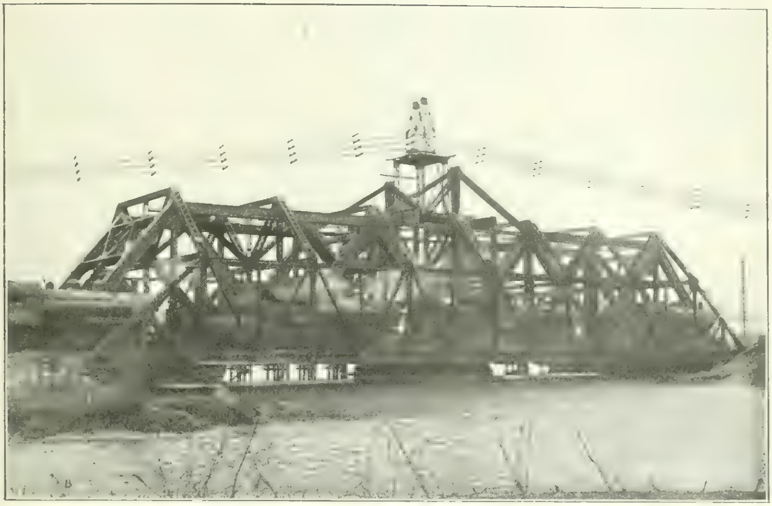


FIG. 1.—FOUR-TRACK, CENTER-BEARING, RAILROAD DRAW SPAN AT CONNEAUT HARBOR, OHIO, DURING LOADING TEST.

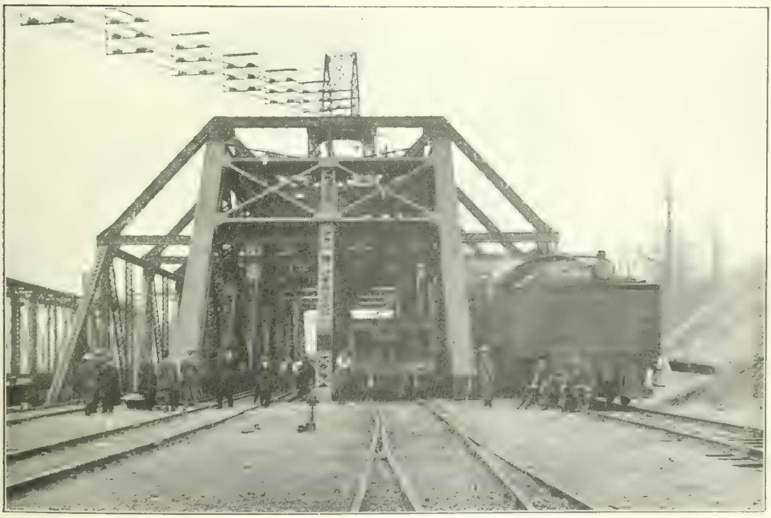


FIG. 2.—END VIEW OF CONNEAUT BRIDGE DURING LOADING TEST.

FIG. 1.—CONNEAUT DRAW SPAN DURING ERECTION. COMMENCING TO PLACE THE OVERHANG.

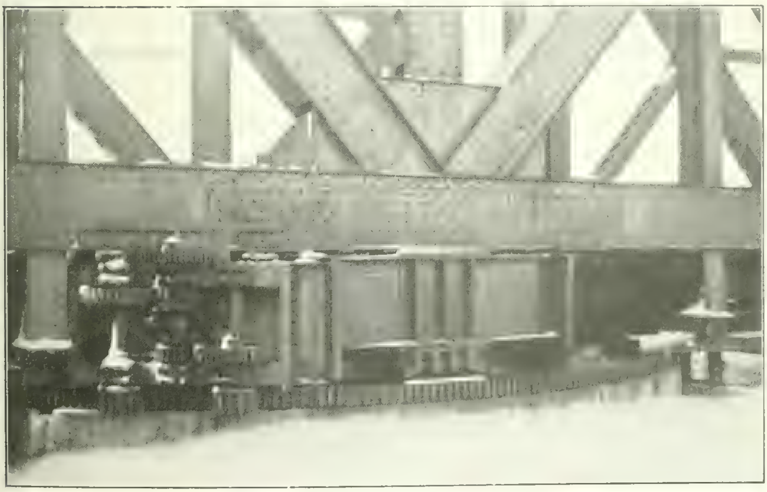


FIG. 2.—CONNEAUT DRAW SPAN. CENTER CARRYING GIRDERS, AND RACK AND PINIONS.

Fig. 1, Plate XV, shows the structure during erection, when the placing of the overhangs had just begun. Fig. 2, Plate XV, shows the central carrying girders and the rack and pinions.

The structure was calculated for Cooper's *E*-60 live load on four tracks, by the American Railway Engineering and Maintenance of Way Association Specifications. It was designed in the Designing Office of the American Bridge Company, at Pittsburgh, Pa., and fabricated and erected by them for the Bessemer and Lake Erie Railroad Company, H. T. Porter, M. Am. Soc. C. E., Chief Engineer.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

THE LARAMIE-POUDRE TUNNEL.

By Burgis G. Coy, Assoc. M. Am. Soc. C. E.

To be Presented April 17th, 1912.

The Laramie-Poudre Tunnel, one of the most important features of the irrigation system now being constructed by the Laramie-Poudre Reservoirs and Irrigation Company for the Greeley-Poudre Irrigation District, has recently been completed, and the remainder of the system is advanced so far that water can probably be furnished for the lands in the district during the season of 1912.

The Greeley-Poudre Irrigation District comprises an area of 125 000 acres of arid land in Weld County, Colorado, in the Valley of the Cache La Poudre River. This land is adjacent to but above the present irrigated area of the Cache La Poudre Valley, and, when supplied with water, will be as productive as any now under cultivation. As the normal flow of the Cache La Poudre River had been already appropriated, it was necessary to look to other drainage areas for water before the present cultivated area could be extended.

The initial steps which led to the development of the Greeley-Poudre Irrigation System were taken in 1902, although it was not then contemplated that this district should ever come into existence. The season of 1902 being a dry one, many of the farmers under the existing ditches found themselves short of water, and began to look around

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

for an additional supply. Messrs. Wallis Link and A. I. Akin, of Fort Collins, Colo., being familiar with the head-waters of the Laramie River, started an investigation to determine whether or not they could divert a part of the waters of that stream into the Cache La Poudre River to supply their crops in time of shortage. It remained for them and their associates to lay the foundation of what has been developed and perfected into the Greeley-Poudre System, which will require the expenditure of approximately $5 000 000 for its construction.

The first plan was to divert some of the tributaries on the west side of the Laramie River, through a ditch, at an elevation about 10 500 ft., into the West Fork of the Laramie, above the head-gate of the Sky Line Ditch, which had already been built and was being operated by the Water Supply and Storage Company, diverting water from the West Fork of the Laramie through a low pass into Chambers Lake, the head of the Cache La Poudre River. The Sky Line Ditch is shown on Fig. 1, Plate XVII. An important part of this plan was the development of a number of small natural lakes, known as the Link Lakes, on the heads of these tributaries, into storage reservoirs, and the operating company was known as the Link Lakes Company, and later, as the Laramie-Reservoirs and Irrigation Company. Further investigation, however, proved that by a tunnel, at an elevation of approximately 8 600 ft., through Green Ridge, the divide between the water-sheds of the Laramie and Cache La Poudre Rivers, a much larger supply of water could be developed.

In the spring of 1907 the Laramie-Reservoirs and Irrigation Company was consolidated with the Mitchell Lakes Reservoirs Company and the Eastman Canal and Reservoir Company, two small reservoir companies operating in the Poudre water-shed, forming the Laramie-Poudre Reservoirs and Irrigation Company; and the tract of land later formed into the Greeley-Poudre District was selected as the most feasible for its development.

The Greeley-Poudre system is naturally divided into two parts, the mountain or collection system, and the plains or distributing system. The principal features of the mountain division are the east and west side collection ditches, 8 and 4½ miles long, respectively, on either side of the Laramie River (Fig. 1, Plate XVI). These intercept the flow of the numerous tributaries and divert it back to a reservoir known as

FIG. 1.—LARAMIE RIVER VALLEY, LOOKING SOUTH TOWARD THE TUNNEL

FIG. 2.—MEDICINE BOW RANGE, FROM DEADMAN HILL.

Tunnel Reservoir, which lies in the bed of the river and from which the water is diverted by the Laramie-Poudre Tunnel through Green Ridge into the Cache La Poudre River. Each of these collection ditches has a capacity of 275 cu. ft. per sec., where it discharges into the reservoir, and the capacity from there to the head is decreased in proportion to the water collected.

The cross-section of the tunnel is 7½ ft. high and 9½ ft. wide; its slope is 1.7%, and its capacity is 800 cu. ft. per sec. As it was anticipated that the corners would not break out square without extra drilling work, the dimensions were made large enough to give a minimum section of 62 sq. ft., and still leave quite an area in the corners, the cross-section thus approaching nearer an ellipse than a rectangle of the given dimensions. As actually constructed, however, the section is nearly rectangular, thus giving a section considerably larger than the minimum required, with a corresponding increase in capacity.

The system receives the drainage from the east slope of the Medicine Bow Range (Fig. 2, Plate XVI) and the west slope of Green Ridge, located in Townships 7, 8, 9, and 10 North, Ranges 9 and 10 West, of the 6th Principal Meridian, and at elevations ranging from 8 600 to more than 14 000 ft.

The distributing system includes the main canal, diverting the water from the Cache La Poudre River, and the distributing laterals and several reservoirs. The aggregate length of canal and laterals is 300 miles, and the storage capacity of all the reservoirs of the system aggregates 100 000 acre-ft.

In September, 1909, the final location of the tunnel was begun by a party of five men under the writer's direction. A base line, approximately 2 600 ft. long, was laid out in a level place in the Laramie River Valley, and a triangulation system was established from which the length and bearing of the tunnel were determined. Levels were run over the hill and bench-marks were placed at each 100 ft. in elevation; these were subsequently checked by another man. The top of the hill is practically 1 000 ft. above the Laramie River and 1 500 ft. above the Poudre River. A dense growth of jack pine and quaking asp covers the top of the hill, and a great deal of cutting was necessary in establishing the triangulation system and the tunnel line. The final line as first located required eight set-ups of the transit to

get over the hill (Fig. 1), but later this was reduced to six when the permanent points were set.

The contract for the construction of the tunnel was let to Mr. J. A. McIlwee, of Cripple Creek, who had made a record on the Cripple Creek drainage tunnel. The Company agreed to put up and furnish the camps at each end, build a power-plant, and furnish rails, pipes, cars, etc., and the contractor was to furnish his own drills, steel, tools, etc. Mr. McIlwee moved to the site of the east portal on November 25th, 1909, established a temporary camp in tents, and erected a small steam compressor and boiler to use until the Company could erect the permanent camps and power-plant. Although the weather was extremely cold and the ground covered with snow most

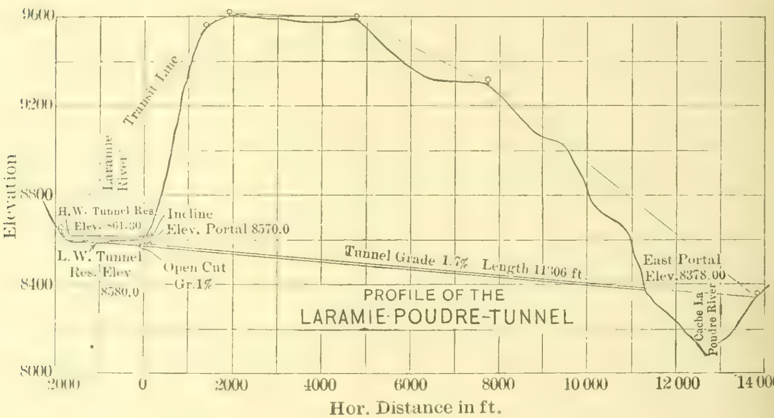


Fig. 1.

of the time, at the end of 30 days he was ready to work, and on Christmas Day the first blow in the actual driving of the tunnel was struck at the east portal. A similar temporary camp and power-plant was erected at the west portal, but, being less accessible, especially at that season of the year, work was not started until nearly a month later. At the east portal 800 ft. of tunnel were driven with this temporary plant, but at the west portal not much tunnel proper was driven before the permanent plant was ready, most of the time having been spent in driving an incline to get down to the tunnel grade.

The contract for installing the power-plant was awarded to the Hampson Fielding Engineering Company, of Denver, Colo., which began operations about December 1st, 1909, and had the plant com-

Fig. 1.—West Fork of Laramie River, Showing Sky Line Ditch.

Fig. 2.—East Portal Camp on Cache La Poudre River.

pleted and ready for operation on March 15th, 1910. All the buildings at both ends were erected by the Company by force account.

All the supplies, machinery, and building material had to be freighted in from Fort Collins, Colo., to the east end, and from Laramie City, Wyo., to the west end. The distance from Fort Collins to the east portal is about 65 miles, and the distance is about the same from Laramie City to the west portal. The handling of all this material over mountain roads for such distances, and in the dead of winter, was no small accomplishment. Some of the road was newly built, and was very rough. All traffic to the east portal had to go down Pingree Hill, where a descent of 1 260 ft. is made in 2.7 miles, with several pitches steeper than 20%, and usually covered with ice and snow. Although as great a load as 11 000 lb. was hauled on a wagon, there was no serious accident, and but small loss of material. The price paid for freighting was $1.40 per 100 lb. for the heavy machinery and $1.12½ for lighter stuff.

The Poudre River, near the east portal of the tunnel, has a very steep grade, and affords an excellent site for a power-plant. This was taken advantage of for power for the main plant to drive the tunnel. A 10-ft. rock-filled crib dam was built across the river (Plate XVIII) about 1½ miles above the tunnel site, and from this a 22-in. wooden stave pipe leads down the river for 8 500 ft. to the power-plant, where three Pelton wheels are operated under a static head of 278 ft.

A 48-in. single-nozzle wheel, with a maximum capacity of 130 h.p., running at 245 rev. per min., was used to drive an air compressor for operating the drills at the east end, being belted to a 72 by 16½-in. face pulley from a 40 by 16½-in. face driving pulley. The nozzle on this wheel was controlled by the pressure in the air receiver. The compressor was of the Ingersoll-Rand, Imperial, Type 10, cross-compound, 17 by 10 by 14 in., having a capacity of 600 cu. ft. of free air per min., at 135 rev. per min., maintaining a pressure of 135 lb. per sq. in. at the receiver. It was also equipped with an automatic unloading device controlled by the pressure of the air. A 10 by 3-ft. receiver was placed just outside the power-house, and a similar receiver was placed inside the tunnel. The air line for the first 4 000 ft. from the receiver was 4 in. in diameter, then 3 in. for 3 000 ft., and 2 in. for the remainder of the distance; it was reduced at the manifold to the ¾-in. air pipes for the drills.

A Connorsville blower, with a capacity of 13 cu. ft. per rev., running at 225 rev. per min., was used for ventilating the tunnel, and required from 20 to 30 min. to suck the gas out after each round was shot. This blower was operated by a 48-in. single-nozzle wheel, mounted on the blower shaft, and guaranteed to develop not less than 25 h.p. A 15-in. ventilating pipe was laid from the blower into the tunnel and within 100 ft. of the breast, and was extended as the work progressed.

For lighting purposes in both camps, and for power for the west end, a 150-kw., General Electric, 3-phase, 60-cycle, 2 300-volt generator, running at 600 rev. per min., was used. This was belted to a 48-in. water-wheel, running at 245 rev. per min., operated by a 12-in. double nozzle. There were four nozzle tips, two bored for 125 h.p. each, one for 90 and one for 80 h.p., so that any two could be used in combination as desired, giving an efficiency of 79% when developing 210 h.p., normal load, and 75% when developing 250 h.p. The driving pulley on the water-wheel was 80 by 19-in. face; the driven pulley of the generator was 32 by 19-in. face. A special oil-pressure governor controlled the speed of this wheel.

The equipment at the west end was the same as that at the east end, with the exception of the operating power, all machinery being run by motors, and, for the purpose of hoisting muck out of the tunnel, an F. M. Davis, 25-h.p., electric hoist, was used, having a capacity of 5 000 lb. at a speed of 120 ft. per min. The electricity for operating the plant at the west end was generated at the plant at the east end. The transmission line was of No. 0, weather-proofed, copper wire, 15 000 ft. long, and reached an altitude of 9 600 ft. in crossing the mountains. At each end a 5-kw. transformer furnished current at 110 volts for lighting the camp; and, at the west end, three 150-kw. transformers furnished current at 440 volts for operating the motors.

At both ends of the tunnel No. 7 Leyner water drills were used up to July, 1910, when No. 8 drills were substituted. For the purpose of supplying water for these drills, a ¾-in. pipe was carried into the tunnel. At the east end the supply was obtained by gravity from a small creek which runs near the portal. The water was run into a steel tank connected with the compressed air line. When the tank was full the inlet valve was closed and the compressed air was turned into

DAM AND PIPE LINE FOR POWER-PLANT ON POUDRE RIVER, EAST PORTAL.

the tank, forcing the water through the pipe to the drills. Two tanks were in use at each end, and one was being filled while the other was being emptied. With this system, freezing caused more or less trouble, but, before the winter of 1910-11 set in, the heading was advanced so far that the tanks could be moved into the tunnel, and the supply was taken from water running on the floor. At the west end the same system was used, except that water was pumped from the Laramie River into a wooden tank on the hillside, above the portal, until the work was advanced so far that steel tanks could be used inside the tunnel.

A No. 2 Leyner drill sharpener was used in the blacksmith shop at each end for sharpening and shanking the drill steel. At the east end the camp buildings (Fig. 2, Plate XVII) included: A combination cook-house and dining-room, 28 by 80 ft., large enough for 75 men; a two-story bunk-house, 28 by 80 ft., containing twenty-two bedrooms, accommodating two men each, with a general sitting-room, bath and wash-rooms; a commissary and hospital, 22 by 38 ft., containing storeroom, medicine-room, doctor's bedroom, patients' ward, and bathrooms; a two-story office building, 26 by 32 ft., containing five bedrooms, sitting-room and office; a power-house 40 by 45 ft., with a small room for the engineer, and a storeroom for supplies; a blacksmith shop, 24 by 24 ft.; a storehouse, 24 by 16 ft.; several 12 by 14-ft. house tents for men who desired to have their families with them; and the usual powder-houses, thaw-houses, barns, and outbuildings. The buildings are all of lumber, and are covered with ruberoid roofing, and the kitchen, bunk-house, and hospital are supplied with running water and sewer connections. The camp at the west portal (Fig. 1, Plate XIX) is similar to that at the east portal, except that the buildings are not of the same sizes, and they are of logs with ruberoid roofs. There is also a transformer-house, in addition to those already mentioned.

As the grade of the tunnel is to the east, conditions were much more favorable for rapid work at the east end than at the west end, where it was necessary to haul all muck up hill, as well as to pump out the water encountered. The grade of the tunnel at the foot of the hill at the west end is 15 ft. below the bed of the Laramie River, and about 1 200 ft. distant from it. It was thought best to start the tunnel (Fig. 1) at the hill, where the formation was solid and water-

tight, and to finish the part back toward the river after the two headings had met. This part, being glacial deposits of sand and gravel, contained more or less water. The tunnel grade is about 40 ft. below the surface at this point, and was reached by an incline about 200 ft. long, starting where the first rock formation showed at the bottom of the hill. After the two headings met, a tunnel was driven back from the foot of the incline toward the river as far as the formation was solid; the remainder was taken out in open cut.

As it was anticipated from the first that more or less water would be encountered at the west end, facilities for handling 700 gal. per min. were provided. A Byron Jackson, two-stage, 5-in. centrifugal pump, direct-connected to a 25-h.p., 3-phase, 440-volt, induction motor, running at 900 rev. per min., was mounted on a truck and kept on a side track at the portal ready to be taken down into the tunnel whenever needed. A 5-in. spiral-riveted water pipe was laid as the tunnel advanced, to which the pump could be connected. It was never found necessary, however, to run this pump, but, for a good part of the time, a small piston pump was in use. This was operated by compressed air from the main air line. A sump and pump station were blasted out at the side of the tunnel, so that the pump would be out of the way and safe from the flying muck, and the pump was set up and connected to the water line. When the sump filled up, the pump was operated until it was empty again. As the tunnel progressed, new sumps were blasted out, and the pump was moved nearer the breast. At the east end all the water flowed out by gravity.

All the drilling was done with Leyner drills mounted on a horizontal bar, which was held in position by tightening it against the walls of the tunnel with a jack-screw, with which one end was fitted (Fig. 2, Plate XIX). The bar was made of a piece of 3-in., double-strength pipe, with a fixed shoe on one end and a screw on the other, and was easily handled and set up by the machine men and their helpers. Some of the holes were drilled with the machines above the bar and some with them below it. Two set-ups of the bar were required to drill the entire round. The upper set-up was drilled from the top of the muck pile while the muck was being cleared away; then the bar was lowered and the lifters were put in. At first two drills were used on the bar, but later it was found that three could be used to much greater advantage. Rounds were drilled from 10 ft.

FIG. 1.—WEST PORTAL CAMP AND DUMP

FIG. 2.—DRILLS ON BAR, AT EAST PORTAL HEADING.

deep with 12-ft. cut holes, breaking a 10-ft. round, down to 7 ft. deep with 8-ft. cut holes, breaking a 7-ft. round.

Fig. 2 is a diagram of the holes as drilled for a 10-ft. round, by three drills on the bar, drilling 21 holes to the round. The holes lettered *R. T.* were drilled by the right-hand machine on the top set-up. Those marked *C. T.* were drilled by the center machine on the top set-up, and those marked *L. T.* by the left-hand machine; likewise, those marked *R. B.*, *C. B.*, and *L. B.* were drilled by the respective machines on the bottom set-up. The holes were started $2\frac{1}{8}$ in. in

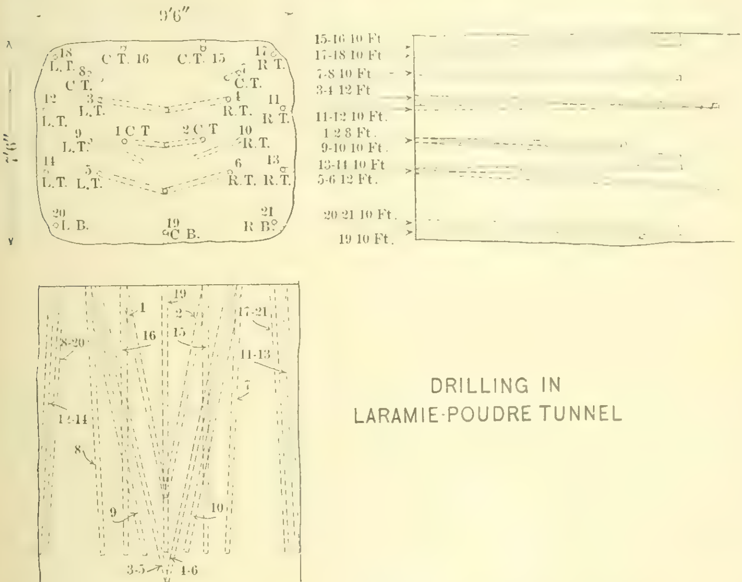


FIG. 2.

diameter and bottomed at $1\frac{3}{8}$ in. It will be noted that each man had but one hole to drill on the lower set-up, and when one man was delayed in finishing his lifter, the others blew out the holes already drilled and loaded them ready to shoot.

The holes were fired in the order numbered in Fig. 2, each being fired independently of the others, by fuses cut to such lengths as would explode them in the proper order. The pairs of holes, 1 and 2, 2 and 3, and 3 and 4, however, being joined or very close together, usually went at the same time, and gave better results when they did so.

The charge varied, both as to the strength and quantity of powder used, according to the depth of the holes and the quality of the rock, but a charge for a 10-ft. round in hard rock was about as follows: Seven sticks of $1\frac{1}{4}$ by 8-in., 100% blasting gelatin were put in the bottom of each of the cut holes and tamped, to within $2\frac{1}{2}$ ft. of the collar of the hole, with 60% dynamite; the remaining holes were similarly loaded with 60 and 50% dynamite. The wrappers were slit and the powder tamped until it filled the hole. German insoloid fuse was used, and 5 x California caps. Hole 21, being the last one fired, threw the muck away from that side of the tunnel, leaving room to operate the lever to tighten the screw in setting up the bar for the next round. Rounds were fired as soon as ready; and, as soon as the smoke was cleared out, usually from 15 to 30 min., the drillers set up the bar for a new round, and the muckers began loading the muck shot down.

The muck was loaded into cars by from four to six men using square-pointed shovels. Steel plates, $\frac{3}{8}$ in. thick, were laid on the floor of the tunnel, extending back about 25 ft. from the breast, and were covered with enough muck to keep them in place while shooting. The muck fell on these plates and was easily shoveled from them. Steel cars, of 18 cu. ft. capacity, were used on a single track. A trip of empty cars was run up close to the muck pile, and all but one were then tipped off the track to one side; the remaining car was loaded and pushed back past the empty cars, one of which was then put on the track and loaded in the same way. When all the cars in the trip were loaded they were pushed up as close to the muck pile as possible and an empty trip was run up close to them and tipped off the track; then the loaded trip was run out to the dump, and a new trip was loaded as before.

At the east end the loaded cars ran out by gravity, and were hauled back by mules. At first one mule, handling a 5-car trip, was able to keep the muckers busy, but, as the haul increased, two mules in tandem were used on 10-car trips (Fig. 1, Plate XX). Two mules in this way were able to handle the muck until the tunnel was in about a mile, and there a siding, long enough to hold about 40 cars, was laid. At the siding the two mules left their empty trip and returned with a loaded one, another mule hauling the empty cars from the switch to the heading in 5-car trips and returning to the switch

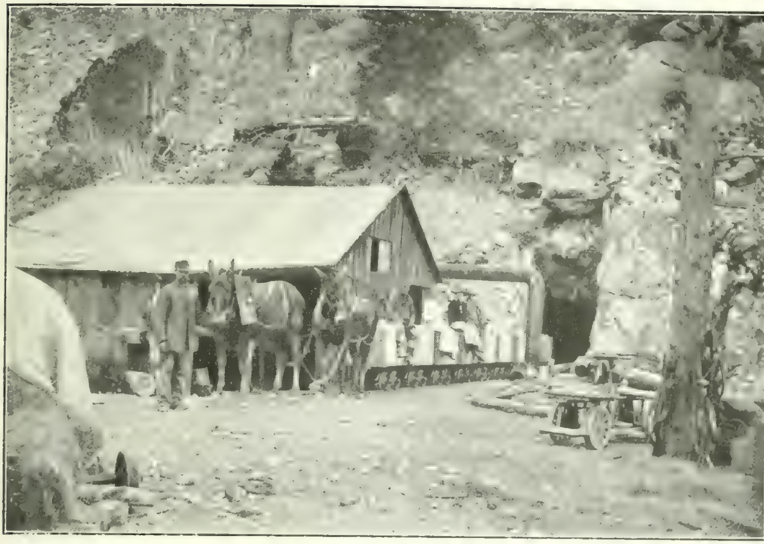


FIG. 1.—TRIP OF CARS AT EAST PORTAL OF TUNNEL.

FIG. 2.—DUMPING CARS AT EAST PORTAL OF TUNNEL.

with a loaded trip. As the length beyond the siding increased, two mules and 10-car trips were substituted. The mules took the cars to the dump track, left them for the dumpman to unload and arrange on another siding ready to go in, and returned with a trip already on this siding (Fig. 2, Plate XX).

At the west end a mule hauled the empty cars and the hoisting cable to the breast and did the shifting there, but loaded cars were hauled out by the hoist, taking trips of 12 cars to the foot of the incline and 3 or 4 cars up the incline, where a man with another mule took them to the dump and returned the empty cars to the siding ready to go in again.

Dull steel was brought out on the loaded trip, left at the blacksmith shop as the trip went by, and sharp steel was taken in with the empty trip.

The track, with 18-in. gauge and 16-lb. rails, was laid on the left side of the tunnel; the ventilating pipe, air and water lines were laid on the right side. As the ventilating pipe did not extend nearer the breast than 100 ft., this gave room to handle the cars.

The rock encountered was mostly a hard gray or red granite. Some soft seams were encountered, however, and where these ran in the direction of the tunnel, some timbering was necessary. In all, eighteen different stretches have been timbered, varying from 15 to 400 ft. in length, and aggregating 985 ft. In most cases, however, the rock stood until the tunnel heading was far enough past to allow the timbering to be put in without interfering with the progress to any great extent. The timbering was of the ordinary square-set type, made from round logs and lagged with poles, all of which were cut from the hillsides near by. The pieces in the square sets varied from 9 to 18 in. in diameter, and the spacing was from 3 to 8 ft., according to the quality of the rock supported. The timber used was fire-deadened red spruce, with an occasional stick of white spruce or lodge pole (Fig. 1, Plate XXI). It is the intention to line all these timbered places with concrete during the winter of 1911-12.

The drillers, helpers, and muckers worked in three 8-hour shifts of 3 drillers, 2 helpers, from 4 to 6 muckers, and 1 foreman. Drivers, blacksmiths, and power-house men worked 12 hours. The wages paid were as follows: Drill runners \$4.50, helpers \$4.00, muckers \$3.50,

blacksmiths $4.50, drivers $4.50, and foremen $6.00. In addition to these wages, a liberal bonus was given each month for fast work.

The total length of tunnel driven is 11 306 ft., and the progress for each month was as follows:

January, 1910, east end	302		
February, "	315		
March, "	350	West end	202
April, "	354	"	279
May, "	513	"	336
June, "	429	"	388
July, "	443	"	371
August, "	527	"	293
September, "	485	"	292
October, "	413	"	28*a*
November, "	424		
December, "	482		
January, 1911	609		
February, "	420		
March, "	653		
April, "	583		
May, "	635		
June, "	576		
July, "	416*b*	West end	81*c*
August, "	...	"	107*d*

This gives a monthly average of 308.7 ft. for 7 months at the west end, and 473.7 ft. for 19 full months at the east end; 509.4 ft. per month for the 16 months during which the complete plant was operated, and 525.2 ft. per month for the last year of work; 653 ft. in March, 1911, sets a new record in America for 1 month's work.

This remarkable record was due to the organization of the operating force, the friendly rivalry between the different shifts, and in no small measure to the efficiency of the power-plant which was operated for more than 16 months. The total time lost from all causes aggregated less than 24 hours.

---

a. Work was shut down at west end on October 4th.

b. Headings met July 24th.

c. Work at west end under incline, but handled from east end.

d. Work at west end under incline, completed August 8th.

Fig. 1.—Section of Timbering in Tunnel.

Fig. 2.—Interior of Tunnel at Junction of Headings.

On checking up, after the connection was made, the following errors were found: alignment 0.01 ft.; grade 0.18 ft.; computed length between initial points 11 288.77 ft., measured length 11 288.20 ft., or an error of 0.57 ft. For the alignment, three separate lines were run over the hill from the west to the east, and the mean of these was run back through the tunnel for a center line of the east end work. Three different sets of levels were carried over the hill from the west to the east, and the mean of these was assumed as the correct elevation from which to carry the elevation back through the tunnel. The measured distance through the tunnel is the mean of two measurements. The point at which the headings met was 8 937 ft. from the east portal and 2 351 ft. from the top of the incline at the west portal (Fig. 2, Plate XXI).

Mr. J. J. McIlwee, son of the contractor, was Superintendent at the east end, and Mr. Walter Warner at the west end. Mr. D. W. Brunton, Past-President of the American Institute of Mining Engineers, was Consulting Engineer. Charles R. Hedke, M. Am. Soc. C. E., of Fort Collins, was Chief Engineer until June, 1911, when he was superseded by Mr. L. L. Stimson, of Greeley, Colo. The writer was Resident Engineer in charge of the tunnel, collection ditches, and reservoirs.

From the end of the solid formation on the west side, an open cut extends to the river, a distance of 1 500 ft. The total quantity to be moved is about 35 000 cu. yd., the cuts ranging from 0 to 44 ft. This work is now under contract by Messrs. Ianson and Loesch, of Fort Collins. The first 300 ft. next to the hill consists of gravel and boulders; many of the latter contain from 10 to 20 cu. yd., and require considerable blasting. This part of the work was sub-let to a station gang of Swedes who are doing the work by hand, using a track and cars drawn by a horse to handle the muck. The remainder of this cut is of gravel and clay, and is being done by teams in the usual way.

The controlling works at the west end of the tunnel consist of a set of three steel gates, each with a 5 by 8-ft. opening. They are set in concrete in the usual way for river gates. It was originally planned to have a 50-ft. dam at the tunnel reservoir, giving a draw of 33 ft. through the tunnel, but for the present the dam will be only

26 ft. high, giving a draw of 9 ft., and the gates are put in the cut, near the high-water line.

At the east end of the tunnel the water will be discharged into a concrete box, 30 ft. square and 14 ft. deep. A concrete flume, 30 ft. wide and 50 ft. long, will draw the water from this box, leaving the lower 6 ft. of the box for a water cushion. After rating, the water will be released to run down the hillside to the Cache La Poudre River, about 1 200 ft. away, and 300 ft. below the end of the tunnel.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS
This Society is not responsible for any statement made or opinion expressed in its publications.

FAULTS IN THE THEORY OF FLEXURE.

By Henry S. Prichard, M. Am. Soc. C. E.

To be Presented May 1st, 1912.

Introduction.

As the ordinary theory of flexure is almost universally used, not only in proportioning simple beams, but in the solution of all questions involving the elastic deformation of structural members, the nature and influence of its faults, by reason of which it is not rigidly accurate, but only approximate, should be generally understood.

It is generally recognized that the ideal material and conditions assumed are not wholly achieved, and it is shown in some elaborate treatises on the theory of elasticity, but not ordinarily realized, that, even if it were possible to have ideal material and conditions, the theory would still be faulty; for instance, it is shown by Professor C. Bach,* that a cross-section originally plane does not remain plane during flexure, as is ordinarily assumed, but is forced into a reversed curve somewhat like a long $\int$, only much less pronounced in ordinary materials; and Professor A. E. H. Love† states that the ordinary equation for shear distribution gives an average intensity across the breadth of the section, and that actually the distribution is not uniform, as is tacitly assumed in nearly all textbooks.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

* "Elastizität und Festigkeit," p. 459.

† "A Treatise on the Mathematical Theory of Elasticity," p. 331.

It is not necessary to master profound and highly complicated treatises on elasticity to understand the faults in the theory of flexure, while, for the purpose of allowing for these faults, after they are understood, judgment, assisted by approximations and tests, is of more practical use to engineers than the much involved expressions of mathematical investigators.

For convenience, the further discussion of the subject is divided into sections.

SECTION 1.—DEFORMATION OF CROSS-SECTIONS.

The fact that a cross-section originally plane is forced by flexure into a reversed curve, somewhat like a long $\int$, can be readily shown by marking the position of a cross-section on the sides of a free, good, soft, rubber eraser, such as is used by draftsmen, and then bending it by the thumbs and forefingers, or by loading it, as illustrated by Plate XXII, Fig. 1 being the unloaded, and Fig. 2 the loaded, beam.

The curve developed in an originally plane cross-section by loading the beam can be explained by considering the distortion produced by shear. To simplify the analysis, consider a vertical cross-section of a horizontal beam at a point where there is no bending moment and where, consequently, the strains are due entirely to shear.

According to the theory of flexure, the shear will be greatest at the neutral axis and gradually decrease until it becomes zero at the extreme top and bottom fibers. The theory is correct in this regard, although faulty with reference to the law by which the shear diminishes.

The shear acting on the horizontal and cross-sectional faces of an originally square increment will cause one diagonal of the increment to lengthen and the other to shorten, as in the various increments shown in Fig. 1, and these distortions will be less for each succeeding increment from the neutral axis toward the top and bottom fibers. Consequently, the originally vertical transverse faces of these increments will not remain in the same transverse plane, but will form a curve, as in Fig. 1.

The curves of the successive cross-sections of a beam toward the point of no shear will gradually approach a straight line, and reverse in direction after the point of no shear is passed.

The intensity of the horizontal stresses in successive horizontal fibers will vary in accordance with the changes in the lengths of these

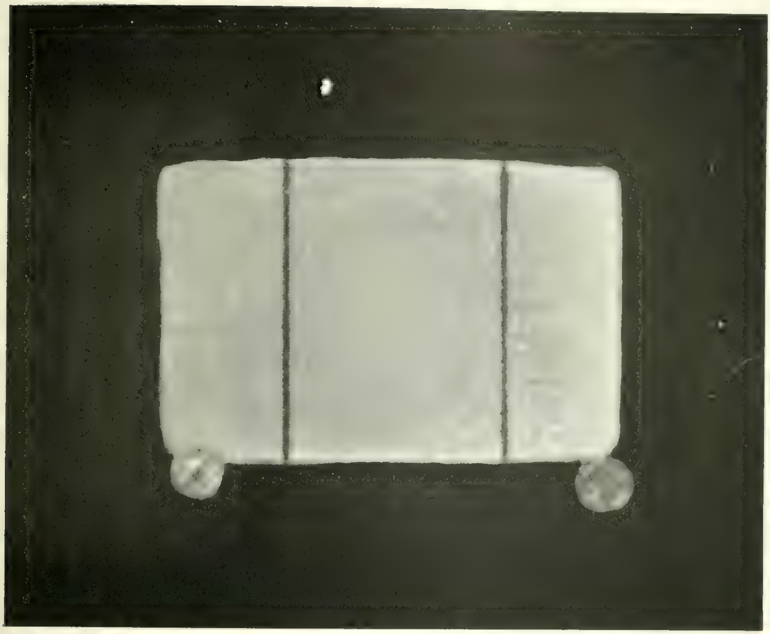


FIG. 1.—RUBBER BEAM: NOT LOADED.

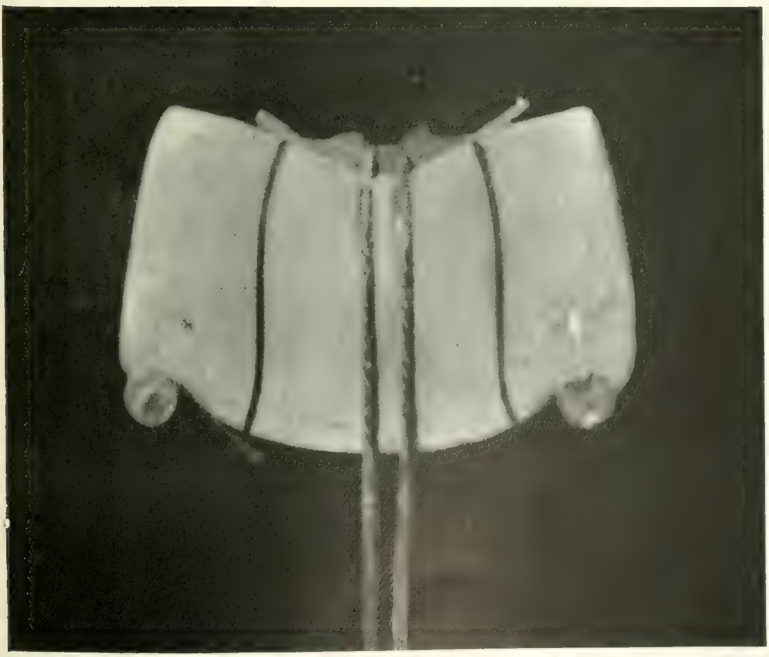


FIG. 2.—RUBBER BEAM: LOADED.

fibers, but these changes, evidently, will not be in direct proportion to the distances of the fibers from the neutral axis, as indicated by the ordinary theory of flexure; hence the ordinary equations for determining the extreme fiber stresses, in which the moment of inertia is a factor in the amount of the stress, are not strictly accurate, because this use of the moment of inertia is based on the proposition that the intensity of the stress in any fiber varies in direct proportion to its distance from the neutral axis.

In these circumstances the questions arise: "Can the theory be corrected in this regard?" and "To what does the error involved amount in practice?"

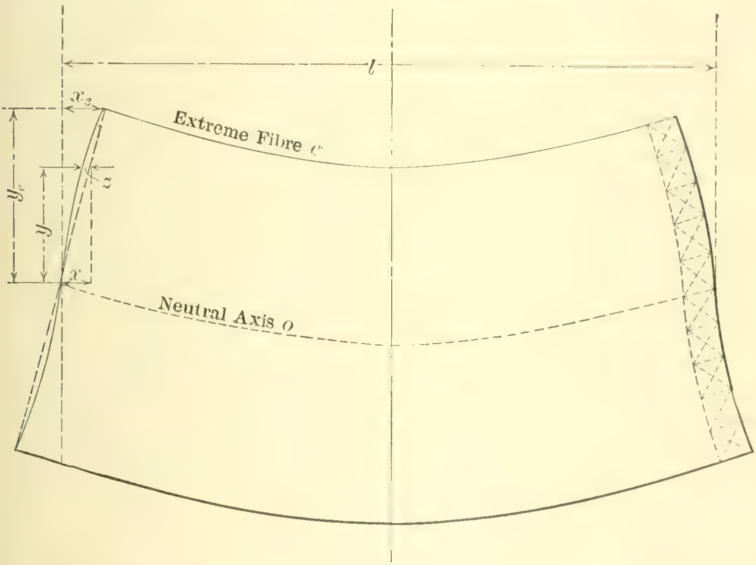


FIG. 1.

An exact general analysis, if developed, would be so complicated, and its application would necessitate so much labor and consume so much time, that it would be wholly impracticable to put it to any general use. It is practicable, however, to determine, in cases selected as criteria, close approximations to the corrections which should be made to allow for the error involved in assuming that cross-sections originally plane remain plane during flexure.

For horizontal beams of constant and usual cross-sections, uniformly loaded within the elastic limit, and with ends simply supported, the

cross-sections at the center will remain vertical during flexure (as is evident from the symmetry of the condition as regards the center), the maximum intensity of stress in each horizontal fiber or layer will occur at the center cross-section, and the change in the lengths of the various fibers will be proportional to the maximum intensity of stress therein.

The change, caused by flexure, in the length of each fiber from the end to the center of the beam, is also the amount by which the end of each fiber moved (from its original free position in the vertical plane passing through the end of the neutral axis), as shown in Fig. 1.

Let f = the intensity of the stress in the extreme fiber,
y = the distance of any fiber from the neutral axis,
y_e = the distance of the extreme fiber from the neutral axis,
x = the shortening of any fiber between the center and end of the beam, indicated by the ordinary theory of flexure for a given f,
x_e = the shortening of the extreme fiber between the center and end for a given f,
z = the difference between x and the true shortening of any fiber between the center and end of the beam,
a' = the area of any horizontal layer of the cross-section,
M = the bending moment at the center of the beam corresponding with f, as determined by the ordinary theory of flexure,
M' = the true bending moment corresponding with f,
l = the length of the beam.

By the ordinary theory of flexure:

The intensity of the stress in any fiber is

$$\frac{f\,x}{x_e} = \frac{f\,y}{y_e}$$

For any given f, M is constant for all values of l, and

$$M = \sum_0^e \left(\frac{f\,a'\,x\,y}{x_e} = \frac{f\,a'\,y^2}{y_e}\right) = \frac{f\,I}{y_e} \ldots\ldots\ldots\ldots (1)$$

By a refined method:

$$M' = \sum_0^e \left(\frac{f\,a'\,x\,y}{x_e} - \frac{f\,a'\,z\,y}{x_e}\right) \ldots\ldots\ldots\ldots (2)$$

The mean intensity of stress in the extreme fiber between the center and the end of the beam equals $\frac{2f}{3}$.

$$x_e = \frac{f\,l}{3\,E} \quad \text{.......................} \quad (3)$$

From Equations 1 and 3, Equation 2 becomes

$$M' = \frac{f\,I}{y_e} - \left(3\ E \sum_0^e a\ z\ y\right) \div l \quad \text{..............} \quad (4)$$

As a study for a contemplated paper on plate-girder design, the writer made a comparison, which is given in Table 1, between the results of Equations 1 and 4 for the steel beams shown in Figs. 2A, 2B, 2C, 2D, and 2E.

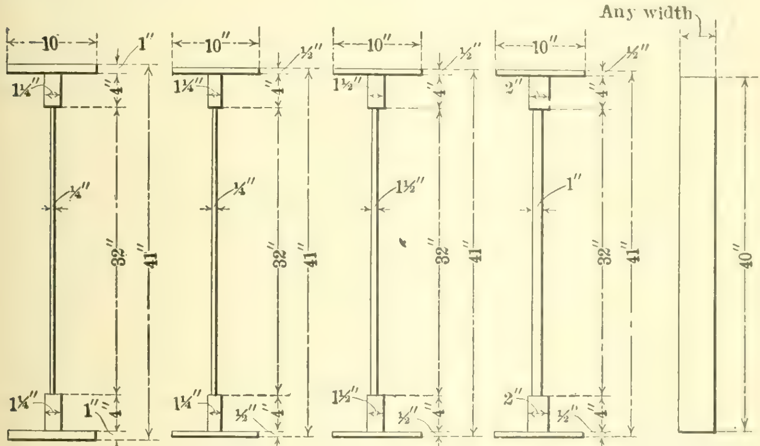


FIG. 2A. FIG. 2B. FIG. 2C. FIG. 2D. FIG. 2E.

In computing the numerical value of the true bending moment, the values of z were determined for the distribution of shear indicated by the ordinary theory of flexure, which distribution thus applied tends toward a slight under-estimate of the value of the bending moment; the lateral contraction in the web accompanying and at right angles to the extension from tension was taken as one-third of the extension, and the lateral extension accompanying and at right angles to the contraction from compression was taken as one-third of the contraction, which ratio is, if anything, somewhat greater than the mean of experiments; and the summation in the second member of Equation 4 was rendered simple and closely approximate by the homely device of dividing the beam into a considerable number of finite

elements and considering the mean shear in each as the average of the extremes, which tends toward a slight over-estimate of the value of the bending moment. The net result of these approximations is to over-state slightly the error involved in the assumption that originally plane cross-sections remain plane during flexure.

In determining the maximum length for which shear is the governing consideration, the greatest permissible intensity in shear was taken as three-fourths of that in tension.

TABLE 1.—Giving, for the Beams Shown in Figs. 2A, 2B, 2C, 2D, and 2E, the Percentages by which the Indicated Capacity for Uniformly Distributed Load, when Computed by the Ordinary Theory of Flexure, Using the Extreme Fiber Stress as the Criterion, Should be Reduced to Allow for the Error Involved in Assuming that Originally Plane Cross-Sections Remain Plane During Flexure.

Beam in figure.	Ratio of web area to total area.	Coefficient.	Percentages by which Indicated Capacity should be Reduced. For Length ÷ Depth, as below.		Percentages by which Indicated Capacity should be Reduced. For Length ÷ Depth equals 10.
(1)	(2)	(3)	(4)		(5)
2A	28 to 100	219 400	332″ ÷ 42″ = 8.0	2.0	1.24
2B	36 to 100	153 700	234″ ÷ 41″ = 5.7	2.8	0.91
2C	54 to 100	122 700	134″ ÷ 41″ = 3.3	6.0	0.73
2D	71 to 100	94 000	88″ ÷ 41″ = 2.1	11.0	0.56
2E	100 to 100	81 100	40″ ÷ 40″ = 1.0	37.0	0.51

For girders 2A, 2B, 2C, and 2D, shear governs when length is less than given in Column 4.

When the lengths of the above girders are more than twice their depths, the approximate percentages of reduction can be obtained by dividing the coefficients given in Column 3 by the squares of their lengths, in inches.

In obtaining the ratios given in Column 2, the web was taken the full depth of the beam.

The beams from which Table 1 was computed have thin webs, but the webs can be increased without affecting the results, provided corresponding changes are made in the flanges.

A consideration of Table 1 shows that for very short beams the erroneous assumption that originally plane cross-sections remain plane during flexure leads to a considerable over-estimate of their capacity to resist bending stresses, while for long beams and those of moderate length the error is of little practical importance.

Section 2.—Manner of Loading.

Beams frequently rest on supports and occasionally are suspended; loads are applied sometimes at the top and sometimes at the bottom; and, in the case of I-shaped beams, the loads and reactions are sometimes distributed as nearly as practicable over the entire depth of the web.

A fault, and, as far as concerns I-shaped beams with thin webs, the most serious fault, in the theory of flexure is that it does not take into account the manner in which beams are loaded and supported, but is developed on the tacit assumption that just the right proportion of each load and reaction needed to produce the theoretical changes in shear reach each horizontal layer of the beam without producing any stress in the layers above or below.

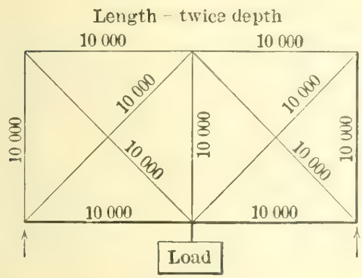


Fig. 3A.

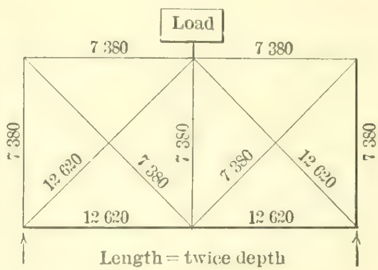


Fig. 3B.

When this tacit assumption is not realized, the distribution of shear and horizontal stress will not be the same as indicated by theory, and vertical tension, or compression, as the case may be, will be produced in the web.

A double lattice girder with a length of twice its depth, shown in Figs. 3A and 3B, is chosen to illustrate by analogy the principles involved, because it is a simple case in which the stresses can be readily determined from the laws of elasticity.

In such a lattice girder the changes in the stress in the diagonals occur at the top and bottom, and if the loads and reactions are applied in suitable proportions at these points there will be no strain in the vertical members, in fact, no need for vertical members; but, if otherwise applied, vertical members will be strained.

In the case illustrated in Fig. 3A the loads and reactions are applied entirely at the bottom and the vertical members are therefore strained. The girder is designed so that the stresses in each member have an intensity of 10 000 lb. per sq. in. If, now, the position of the load is changed from the bottom to the top, as in Fig. 3B, more members will be strained in one system than in the other; therefore, it will take less load to produce the common deflection in one system than in the other, and the stresses will be less in one than in the other: In fact, the stresses will be increased in the members of one system and decreased in those of the other by 26.2 per cent.

By analogy, it is proper to infer that similar differences occur in the distribution of shear and horizontal stresses in beams, and should be considered, when the beams are very short, in gauging their capacity. The percentage of difference rapidly decreases with increase in length, and is inconsiderable in beams of ordinary lengths.

It is usual and necessary in designing built I-beams, known as plate girders, to provide for the vertical compression in the webs, from heavy concentrated loads and reactions, by reinforcing the webs with vertical stiffeners between the flanges. As is well known, it is not customary to do this with rolled I-beams. The only other way of avoiding the overstraining of the webs, in such cases, is to use I-beams in which the webs and flanges are proportioned so that there is sufficient metal in the webs to resist, not only the shear indicated by the ordinary theory of flexure, but, in addition, the tendency of loads applied at the top and reactions applied at the bottom to crush and buckle them.

Architects and engineers should give earnest attention to this phase of the subject. The old and tried shapes, which for many years have been standard for I-beams, have fairly thick webs and well and amply proportioned connections between the webs and flanges; but new shapes, made possible by new methods of rolling, are now rolled which have a greater proportion of metal in the flanges, and for which greater strength in proportion to their weight has been computed by the ordinary theory of flexure and unreservedly claimed, but which have webs in which resistance to crushing and buckling under concentrated loads and reactions has been considerably reduced, as compared with the resistance of the webs in the old shapes.

SECTION 3.—DISTRIBUTION OF SHEAR.

The ordinary equation for distribution of shear, criticized by Professor Love, is as follows:

Let Q = the total shear on any cross-section of a beam of constant cross-section.

q = the intensity of the shear at any point in the cross-section. (See text below and conclusion at end of this section.)

m = the statical moment of that portion of the cross-section outside of the horizontal line in which intensity of the shear is obtained, taken about the neutral axis.

b = breadth of the cross-section at the point where the intensity of the shear is obtained.

I = the moment of inertia of the entire cross-section.

$$q = \frac{Q\,m}{I\,b} \qquad (5)$$

This equation is usually given as applicable to solid sections of beams of all possible shapes. Except for the influence of the faults discussed in Sections 1 and 2, it really gives, as pointed out by Professor Love, the mean or average shear across the breadth of the cross-section. The tacit assumption, in most of the textbooks, that the intensity of the shear is uniform across the breadth of the cross-section, can be analyzed.

FIG. 4A.

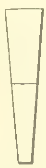


FIG. 4B.

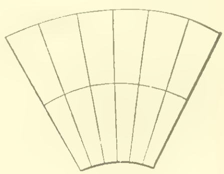


FIG. 4C.

If a number of very thin, independent, equal, rectangular beams are placed side by side, as in Fig. 4A, and then loaded, the portion of each in compression will be laterally expanded and the portion of each in tension laterally contracted, as in Fig. 4B; and, if the loads on each are suitably varied, by increasing them from the center toward the outside beams so as to produce the necessary deflections, and if the sides of the beams are brought into contact, they will collectively appear as one beam with a cross-section bounded on the top and bottom by curved lines and on the sides by lines inclined toward each other, as in Fig. 4C.

The elemental beams, on account of their extreme thinness, have no lateral stiffness, and can be brought into contact by lateral forces so small that the stresses they produce are negligible.

If, without disturbing the position or shape of the elemental beams, their sides are now joined so that the hitherto separate beams form a single homogeneous beam, of which they are equal vertical layers, there will be no stress or shear on their vertical sides, but each layer will be in the same condition of stress and shear as it was when an independent beam; and the shear on the combined beam will not be uniform across the cross-section, but will increase from the center outward.

If, after joining the original elements, the load on the intermediate vertical layers is increased to equal the load on the outside layers, each intermediate layer will deflect, but, in so doing, will transmit part of its load to the adjacent layer toward the outside. The outside layers, therefore, will continue to carry more than a *pro rata* share of the total load, and therefore have more than a mean intensity of shear.

For very broad, very shallow rectangular beams, such as could be formed by a wide, thin plate, the difference in distribution of shear across the breadth of the cross-section is considerable, but, for ordinary rectangular cross-sections, it is evident that the lateral deformation affects the deflection of the different vertical layers so little, in comparison with the total deflection, that there will be hardly any appreciable variation in the shear across the breadth of the cross-section.

These conclusions agree with those of St. Venant, who was the first to make a satisfactory mathematical investigation, and his conclusions were endorsed by Sir William Thompson (Lord Kelvin).*

The influence of lateral deformation on deflection, and, consequently, on distribution of shear, will similarly be of little consequence in solid beams with round, oblong, diamond, or other symmetrical cross-sections, which are not unduly broad and gradually reduce in breadth from the neutral axis toward the extreme fibers, as in Figs. 5A, 5B, 5C, and 5D.

If the distribution of shear in such a beam was analogous to the distribution in a large number of very thin independent vertical beams

* Encyclopædia Britannica (Ninth Edition), Vol. VII, p. 809.

having the same deflection, and, in the aggregate, the same cross-section as the beam under consideration, the load carried by, and, consequently, the shear on any cross-section of, any one of the vertical layers, as compared with the entire beam, would, unless the beam was very short, be closely proportional to their respective moments of inertia, and the mean intensity of shear would be closely proportional to their moments of inertia divided by their areas; that is, to the square of their radii of gyration. (This proposition is based on the ordinary equations for deflection, with the qualifying word "closely" added on account of the faults discussed in Sections 1 and 2, and of the omission from the ordinary equations of the influence of shear on deflection.) Further, cross-sections of the vertical layers, being rectangular, would, according to Equation 5, have a maximum intensity of shear exceeding the mean intensity in the proportion of 3 to 2. Applying these propositions to the center vertical layer:

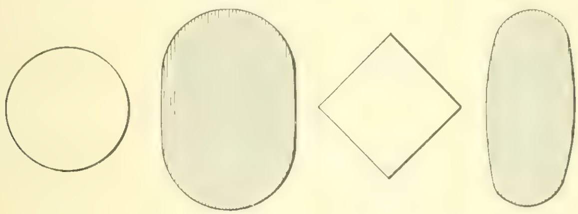


FIG. 5A. FIG. 5B. FIG. 5C. FIG. 5D.

Let n = the radius of gyration of the entire cross-section,
and h = the depth of the center vertical layer,

The square of the radius of gyration of the center vertical layer $= \frac{h^2}{12}$,

The ratio of the mean intensity of shear in the center vertical layer to the mean intensity on the entire cross-section is as $\frac{h^2}{12}$ is to r^2 . . . . (6)

And the ratio of maximum intensity of shear to mean intensity of shear on the entire cross-section, is as $\frac{h}{8}$ is to r . . . . (7)

Table 2 is a comparison of ratios of maximum to mean intensity for various cross-sections, as derived by applying Equations 5 and 7, respectively.

TABLE 2.

Cross-section.	By ordinary Equation, 5.	By Equation 7.
Rectangular	3 to 2	3 to 2
Round	4 to 3	2 to 1
Square diamond	1 to 1	3 to 1

The assumption on which Equation 7 is based, that the vertical layers act like independent beams having a common deflection, is not tenable, however, as the deformation from shear, illustrated in Fig. 1, in adjacent independent beams would not match, but would be greatest toward the center. In the united section each successive vertical layer, from the center toward the outside, in distorting would transmit some of its shear to the adjacent section. Hence the ratio of maximum to mean intensity of shear would be intermediary between the values indicated by Equations 5 and 7.

For the square diamond there is another method of determining the maximum shear, the results of which are suggestive. If the load is resolved into components parallel to the directions of the sides of the beam, and if the intensity of the shear from each component is derived by Equation 5 (which is a close approximation for a square cross-section with the load thus applied), and if the maximum intensities of the shear from each component are combined, the ratio of maximum to mean thus obtained is 3 to 2, which is the same as for rectangular cross-sections, and probably not far off for any of the cross-sections in this class.

The distribution of shear in beams with solid rectangular, round, oblong, and diamond, cross-sections is of academic rather than of practical interest, as shear is not a critical matter in such beams unless they are very short, in which case, owing to the faults discussed in Sections 1 and 2, the ordinary theory of flexure is too faulty to use, and experiments should be the criteria.

In giving the ordinary equation (Equation 5), textbooks should state that q is the mean intensity of shear across the breadth of the cross-section at any point, and that, for rectangular cross-sections and webs of I- and T- beams, the intensity of the shear is nearly uniform across their breadth, but that it varies for other forms of cross-sections.

SECTION 4.—BUCKLING OF WEBS AND FLANGES.

The ordinary theory of flexure, besides being in some respects faulty, is incomplete in that it does not indicate the buckling which under certain conditions takes place in the webs and top flanges of certain types of beams.

This phase of the subject is susceptible of further analysis, but the methods of dealing with it will probably always remain somewhat empirical.

When the compression flange is supported at such intervals that the compression is nearly constant from point to point, the practice of limiting the intensity of the compression to that allowed by good column practice cannot be much in error. When the compression flange of a beam simply resting on end supports is laterally supported only at the ends, it differs from a column in having the compression increase toward the point of maximum from zero at the ends, instead of being constant throughout. Under these conditions, the tendency to lateral deflection is somewhat less than it would be if the flange was a column. In usual cases, for beams of constant cross-section, the length of the equivalent column might be taken as 10% less than the length of the beam, between end lateral supports, without undue risk.

In deep beams with thin webs the tendency to buckle is not confined to inclined and vertical directions, nor does it occur only at the ends and points where the loads and reactions are concentrated. There is likewise a tendency to buckle in a horizontal direction from direct compression at points between the neutral axis and the compression flange, and this tendency increases toward the point of maximum bending moment. The tendency of compression, in lines inclined at 45°, to buckle the web is offset, in part at least, by the contra tendency of tension at right angles thereto to take out buckles.

At points where the web is stiffened to resist concentrated loads and reactions, the stiffeners, if properly arranged, receive direct compression, but at other points the function of stiffeners is, as their name implies, simply to stiffen, that is, to increase the resistance of the web against lateral deflection.

The reinforcement of the webs to prevent crushing and buckling at points of concentrated loads and reactions is sometimes advisable in rolled beams, especially in some of the recent shapes referred to in Section 2, but the stiffening at other points, while often necessary in

built beams, is hardly likely to be needed in rolled ones, as the ratio of web thickness to depth is probably sufficient in beams of the proportions thus far rolled, to avoid this necessity.

Built beams or plate girders, as they are usually termed, have so many special points that a discussion of their details is reserved for a separate paper.

Section 5.—Faulty Application of Theory.

In addition to making provision in designing for faults and omissions in the ordinary theory of flexure, engineers should guard against faulty application of the theory. It is a common practice to use a single unsymmetrical section, such as an angle or channel, as a beam, and to compute its nominal strength by the theory of flexure. Actually, the theory of flexure does not give the stress in such beams. Take a channel, for instance; if loads and reactions are applied in the plane of the web, as in Fig. 6A, the flanges receive their stresses from the web eccentrically, the intensity of the stresses is correspondingly increased, and the channel is warped in deflecting; while, if the loads and reactions are applied at the center of gravity of the channel, as in Fig. 6B, there is a tendency to bend the web, and develop serious complex stresses, in addition to those computed from the ordinary theory.

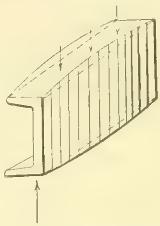


Fig. 6A.

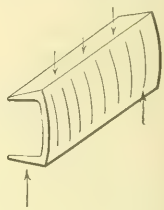


Fig. 6B.

It is generally best to avoid the use of unsymmetrical sections as beams unless connected in symmetrical pairs or otherwise laterally supported. When they are used it should be with a liberal allowance.

In ordinary practice, the stresses in beams are computed only for direct stress in the extreme fiber and shearing stress at the neutral axis; yet, according to the theory of flexure, the critical points in beams under concentrated loads may lie between the neutral axis and the extreme fiber. As an illustration, consider the case of the 30-in. girder beam, Fig. 7, under a load of 439 000 lb. concentrated at the center of a simple span of 79.64 in.:

In these conditions, the shear per square inch at the neutral axis is 12 000 lb. and the extreme fiber stress is 16 000 lb. per sq. in., but

the direct stresses at the foot of the fillet, 2.1 in. from the top of the beam, are: compression 18 660 lb. per sq. in., and tension, at right angles to the compression, 5 220 lb. per sq. in. (and, *vice versa,* 2.4 in. from the bottom of the beam). If the ratio of lateral compression to longitudinal extension is one-third, these compound stresses will produce the same linear compression as would be caused by a simple compressive stress of 20 400 lb. per sq. in., and any shear of more than 142 300 lb., at a cross-section where the extreme fiber stress is 16 000 lb. per sq. in., will produce linear strains greater than would be produced by a simple stress of 16 000 lb. per sq. in.

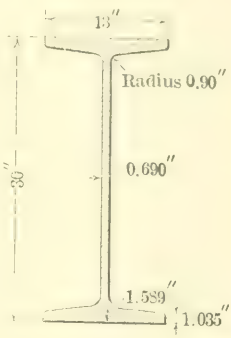


FIG. 7.

In making these computations, I was found to be 8 194.5; m, at neutral axis = 309.12; m, at foot of fillet = 254.35; and q, at foot of fillet = 9 874 lb. per sq. in. (when Q is 219 500 lb.) and 6 400 lb. per sq. in. (when Q is 142 300 lb.).

The maximum direct stresses at foot of fillet were found by the usual equation:

$$\text{Maximum direct stress} = \frac{1}{2} f y \pm \sqrt{q^2 + \frac{1}{4} f y^2} \quad \ldots\ldots\ldots\ldots (8)$$

in which $f y$ is the horizontal stress at the point where the direct stresses are required.

SECTION 6.—OVERSTRAINED BEAMS.

The theory of flexure, even after allowing for its faults, is only strictly applicable within the elastic limit of the material.

The elastic limit, even for specimens from the same melt of steel, will vary greatly, according to the amount of work put on them in rolling, and the original elastic limit, that is, the point where there will be a slight permanent set, is likely to be very low on the first application of the load. There is, however, a point in wrought iron and in soft and medium steel (known as the yield point, and often called the elastic limit), which is well marked in direct tension and compression tests, at which the metal, which before has shown only slight imperfections in elasticity, begins to flow rapidly.

Many experiments have shown that imperfections in elasticity, indicated at stress intensities below the yield point in iron and steel strained to the yield point, disappear, after a rest, on subsequent applications of the load, the explanation being that the original imperfections were caused by initial internal stresses which were removed by overstraining.

There has been much confusion with regard to the elastic limit, and it is not possible to tell from some reports of tests of beams whether the elastic limit recorded was simply an imperfection which the first loading would correct, or whether it was the critical elastic limit. It would be well in all doubtful cases, after beams under test loads have shown some permanent set and before testing them to destruction, to have the loads removed and the beams retested, after a rest.

Solid sections, such as pins, can, according to the theory which considers the effect of overstraining, develop, with a slight and almost inappreciable permanent set, a considerable permanent strength in excess of that indicated by the ordinary theory of flexure. If a horizontal pin without internal stresses is strained to the elastic limit by a vertical load, the intensity of the stresses decreases almost uniformly from the outer fibers to the center, but if the load is increased, the overstrained fibers toward the top and bottom deform so easily, as compared with the others, that, instead of the stresses decreasing uniformly from the extreme top and bottom toward the center, the metal for quite a distance from the top and bottom, if the load is sufficient, will be strained to the elastic limit; thus greatly increasing the capacity of the pin in the direction of the load. If the load is gradually taken off, the fibers toward the top and bottom will be entirely relieved of their stress before those nearer the center, after which tension will be developed in the top and compression in the bottom, forming a couple balanced by compression between the top and the center and tension between the bottom and center; further, the pin will have a permanent deflection. If the load is again applied, the effect of taking off the load will be reversed, without any additional overstraining, unless the original load is exceeded. If the direction of the load is reversed, the internal stresses will tend to lower the elastic limit of the pin.

There is another element which tends to enhance the permanent strength of overstrained solid beams like pins: When iron or steel is overstrained it becomes plastic, but resolidifies when the load is removed. On the removal of the load, the change during a rest from a plastic to a solid state, at a temperature much below the solidifying point, has an effect somewhat analogous to that of sudden cooling on soft and medium steel; it causes the metal to have a finer grain and a higher elastic limit.

Some experiments by Professor Thurston* on 1-in. square wrought-iron beams, 22 in. between supports, and loaded in the center, well illustrate the elevation of the elastic limit from overstraining. One of these beams showed some loss of elasticity under a load of 203 lb. and an extreme fiber stress of 6 700 lb. per sq. in.; yet it subsequently developed, as nearly as could be measured, seemingly perfect elasticity under a load more than eleven times as great.

It may be inferred that overstrained I-beams, especially those in which the metal has not been spread out too thin in the effort to obtain a large moment of inertia, will similarly develop considerable permanent elevation of the elastic limit, provided they are proportioned and laterally supported so that they will not buckle; but suitable tests are needed before this can be regarded as a certainty.

I-beams are peculiarly susceptible to initial internal stresses, and, therefore, to imperfections in elasticity within the yield point, as the flanges, being thicker than the webs, are yet hot after the webs have cooled and in cooling compress the webs horizontally and are themselves brought into tension. If the upper and lower halves of a beam were independent tees, they would bend in cooling so that the flanges would be on the insides of opposite curves, but, being joined, they are prevented from curving and, instead, develop in the web vertical tension at the ends and vertical compression at the center. In the days of wrought-iron beams it was not uncommon to have their webs split horizontally at the ends from such tension.

Conclusion.

The ordinary theory of flexure was gradually developed by noted scientists, beginning with Galileo, and was finally put on a solid mathematical basis by Navier, in 1824. While it is faulty and incomplete,

* Report of the U. S. Board for Testing Iron, Steel, etc., 1881, Vol. I, pp. 455–472.

it is, considering the intricacy of the problems with which it deals, a remarkable approximation, and, when used in the light of reason, an excellent guide within wide limits.

Within the elastic limit, its faults, as applied to well-proportioned and well-supported beams, are practically important only for very short ones; which, unfortunately, have less theoretical resistance within the elastic limit than indicated by the ordinary theory.

The theory assumes that loads and reactions will be applied over the full depth of the beam, and that the profile of the beam and lateral supports are such that it will not buckle or develop weakness locally and will not buckle laterally; but the theory does not show how to insure these conditions, nor does it indicate the modification in the strength of the beam when they are not realized.

In trying to reconcile the theory with facts, the additional difficulties arise: that material has some imperfections in elasticity under stresses much less than what is ordinarily understood as the elastic limit, that wrought iron and soft and medium steel can have their elasticity perfected and its limit elevated by overstraining, and that overstraining introduces internal stresses in beams by which a greater proportion of the strength of the material is utilized under subsequent loads in the same direction (provided there has been no permanent buckling or serious injury).

In addition to the uncertainties incident to the faults in and limitations to the ordinary theory of flexure, there are uncertainties as to the effects of various methods and conditions of manufacture, on beams of various size and profile, which lie entirely outside the scope of the questions dealt with by the ordinary theory and can only be settled by scientific experiments.

The practical man, professedly skeptical in regard to theories, finally adopted the theory of flexure as a criterion for the strength of rolled I-beams (influenced, no doubt, by the statement, in a pioneer manufacturer's pocket book,* of the favorable results of actual tests, made at Trenton, of iron I-beams by a United States Government engineer), and placed such confidence in its results that, when steel was substituted for wrought iron, and new shapes of I-beams were devised, their strength was assumed from theory, without tests; and when, within the last few years, new methods of rolling made it possible to roll

* New Jersey Steel and Iron Company's "Book of Useful Information," p. 33.

deeper beams, wider flanges, and thinner webs, the ordinary theory of flexure was still relied on as a sufficient criterion of the strength of the new shapes adopted.

The changes which have been made in the profiles of I-beams are quite marked, as shown in Figs. 8A, 8B, and 8C.

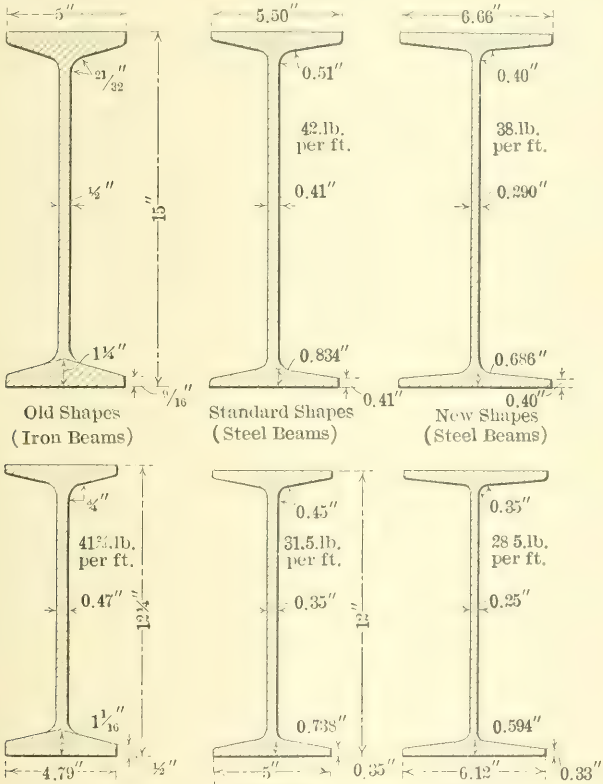


FIG. 8A. FIG. 8B. FIG. 8C.

The more the centers of gravity of the flanges are moved toward the top and bottom, by making the flanges wider and thinner, the greater the computed resistance to bending in proportion to the area of the cross-section; yet there must be some limit beyond which the metal is actually rendered less effective by such spreading and thinning, and this limit can only be determined by the behavior of beams in service and by scientific experiments.

Since the introduction of new shapes for steel beams, 31 beams have been tested by Edgar Marburg, M. Am. Soc. C. E., and

a large number by certain manufacturers for their information and guidance.

In Professor Marburg's tests,* some indicated very low elastic limits, especially for the deeper beams, the lowest being 10 800 lb. per sq. in. for a 30-in. girder beam.

These low elastic limits have caused apprehension in the minds of Professor Marburg and other engineers. That the real original elastic limit, however, as distinguished from the yield point, is likely to be very low has long been known. About 74 years ago Mr. Eaton Hodgkinson found that any stress, however small, was sufficient to produce a set in cast-iron beams;† some 30 years ago the U. S. Board, in making bending tests on wrought-iron I-beams, found the elastic limit as low as 13 000 lb. per sq. in.;‡ and numerous tests at the Watertown Arsenal show low elastic limits for steel of excellent quality (for instance, a test of an eye-bar for the late George S. Morison, Past-President, Am. Soc. C. E., showed a permanent set at 5 000 lb. per sq. in.§).

Professor James Thompson, in 1848, before there were any retests of material to guide him, explained low original elastic limits as the result of initial internal stresses, and stated:

"It appears to me that the defects which he [Hodgkinson] has shown to occur even with very slight strains, exist only when the strain is applied for the first time, or, in other words, that if a beam has already been subjected to a considerable strain, it may again be subject to any smaller strain in the same direction without taking a permanent set."||

This remarkable prediction has been supported by subsequent experiments, the most notable of which are those by Professor Johann Bauschinger, described in his "Communications, 1886," and referred to by Professor Marburg, who stated as follows:

"Accordingly, after an initial stress, of a given magnitude within the elastic limit, has been once developed, the material is afterward perfectly elastic up to the limit of that stress."¶

It is much to be regretted that some of the I-beams tested by Professor Marburg and others were not experimented with, after they

* In a paper by him in *Proceedings*, Am. Soc. for Testing Materials, Vol. IX, 1909, p. 378.

† Report of the British Association for 1837, p. 362.

‡ Report of U. S. Board on Testing Wrought Iron, Steel, etc., 1881, Vol. 11, p. 226.

§ Report for 1901, p. 410.

|| Cambridge and Dublin Mathematical Journal, 1848.

¶ *Transactions*, Am. Soc. C. E., Vol. XLI, p. 227.

had some appreciable but not injurious permanent set, in order to ascertain the effect of overstraining on elasticity. It would be well to have some experiments in which the load would be removed and, after a rest, gradually re-applied, and the elasticity carefully observed and recorded, and others which would develop the greatest load under which, if allowed to remain indefinitely, the deflection would not be excessive and would finally cease to increase.

In Professor Marburg's tests the beams simply rested on supports, and concentrated loads were applied on the top flanges, which had no lateral support even at the ends, a severe combination of conditions, rarely encountered, which cannot be regarded as good practice.

The most extensive of the manufacturer's tests previously referred to were made, under various conditions of loading, on 12-in. and 15-in. steel I-beams.

The conditions of loading and supports were as follows:

A With end connection angles and loads applied at top,

B With end connection angles and loads applied by connection angles through the web,

A With end connection angles and loads applied at top,

D Supported on seat angles with loads applied by connection angles through the web.

The beams were tested for all four of these conditions, with loads applied at the center of the span, and also with loads applied at the third points of the span; that is, (1) with one load, and (2) with two loads.

The tests embraced beams of standard shapes and of new shapes; the averages of the preliminary specimen tests are given in Table 3.

TABLE 3.

	Flange Values.		Web Values.	
	Ultimate tensile strength, in pounds per square inch.	Yield point, in pounds per square inch.	Ultimate tensile strength, in pounds per square inch.	Yield point, in pounds per square inch.
Standard Shapes:				
15-in.–42 lb.	62 166	38 211	60 800	39 141
12-in.–31.5 lb.	62 834	39 222	61 076	38 266
New Shapes:				
15-in.–38 lb.	61 811	40 036	64 768	43 255
12-in.–28.5 lb.	60 588	41 026	64 184	43 647

The bending tests were made at Ambridge, Pa., and the construction of the machine necessitated the placing of the beams in a horizontal position, but they were guided and supported against lateral deflection at intervals of one-third their length.

Table 4, giving the loads which caused permanent sets of 0.1 and 0.4 in. in 15-in. 42-lb. per ft. and 12-in. 31.5-lb. per ft., I-beams of standard shapes, as in Fig. 8B, and 15-in. 38-lb. per ft. and 12-in. 28.5-lb. per ft. I-beams of new shapes, similar to those in Fig. 8C, was compiled from the manufacturer's diagrams of permanent sets.

The loads are stated in terms of the working load, W, computed for the nominal shapes of the beams, as given in manufacturers' pocket-books and shown in Figs. 8B and 8C, on the basis of 16 000 lb. per sq. in. in the extreme fiber.

TABLE 4.—LOADS WHICH PRODUCED PERMANENT SETS OF 0.1 AND 0.4 IN. IN BENDING TESTS OF 15-IN. 42-LB. AND 12-IN. 31.5-LB. I-BEAMS OF STANDARD SHAPES, AND 15-IN. 38-LB. AND 12-IN. 28.5-LB. I-BEAMS OF NEW SHAPES.

Depth of beam, in inches.	Span, in feet.	Loading, as explained above.	Working load; W, in pounds.	PERMANENT SET 0.1 IN.		PERMANENT SET 0.4 IN.	
				Standard shapes.	New shapes.	Standard shapes.	New shapes.
15.....	21	(1) *A*	14 980	3.73 W	3.20 W	4.07 W	3.73 W
15.....	21	(1) *B*	14 980	4.00 W	*3.35 W	4.27 W	*3.92 W
15.....	21	(1) *C*	14 980	3.64 W	3.15 W	4.19 W	3.83 W
15.....	21	(1) *D*	14 980	4.03 W	*3.54 W	4.15 W	*4.07 W
15.....	21	(2) *A*	22 470	3.43 W	3.16 W	3.83 W	3.36 W
15.....	21	(2) *B*	22 470	2.84 W	2.64 W	3.68 W	3.29 W
15.....	21	(2) *C*	22 470	3.53 W	2.82 W	3.89 W	3.34 W
15.....	21	(2) *D*	22 470	2.88 W	2.68 W	3.47 W	3.29 W
12.....	16	(1) *A*	12 000	3.87 W	2.92 W	4.12 W	3.85 W
12.....	16	(1) *B*	12 000	*4.04 W	*3.48 W	*4.21 W	*4.30 W
12.....	16	(1) *C*	12 000	3.92 W	3.22 W	4.33 W	4.21 W
12.....	16	(1) *D*	12 000	*4.22 W	*3.86 W	*4.50 W	*4.50 W
12.....	16	(2) *A*	18 000	3.32 W	2.66 W	3.78 W	3.24 W
12.....	16	(2) *B*	18 000	3.35 W	2.57 W	3.80 W	3.35 W
12.....	16	(2) *C*	18 000	3.58 W	2.73 W	3.89 W	3.51 W
12.....	16	(2) *D*	18 000	3.59 W	2.91 W	3.89 W	3.53 W

* Single tests: In all other cases the averages of three tests are given.

The actual dimensions of the beams of the new shapes that were tested were somewhat different from the nominal dimensions, as their webs were thicker and their flanges thinner, and their actual moments of inertia, and, therefore, their theoretical capacities, were about 5%

less than those of the standard beams of which they are nominally the theoretical equivalents.

It appears, from an examination of Table 4, that the beams sustained for short periods loads more than three times the working load without acquiring permanent sets large enough to be serious when viewed merely as changes in shape. Slight permanent sets, even under the working loads, would not in themselves be objectionable, and would not be alarming if it could be shown that permanent or indefinitely repeated loads of, say, twice the working loads could not produce failure or serious deformation.

On an average, it took 18.6% more load to produce a permanent set of 0.1 in. in the beams of standard shape than in the nominally equivalent beams of new shapes, and 8% more to produce a permanent set of 0.4 in. Whether or not this indicates a corresponding superiority in permanent capacity, what the permanent capacities are, and what permanent sets the beams would take under their maximum permanent loads, are questions to be decided by scientific experiments.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

MULE-BACK RECONNAISSANCES.
Discussion.*

By William J. Millard, Assoc. M. Am. Soc. C. E.

William J. Millard, Assoc. M. Am. Soc. C. E. (by letter).—The criticism of this paper is mostly from the standpoint of an engineer on preliminary and location surveys who fears that his field is being invaded. The impression that the mule is going to supplant a locating party, and that his rider will distribute P. C.'s and P. T.'s around the hills, is rather erroneous. Mr. Millard.

Let it not be forgotten that reconnaissance work belongs to other branches of engineering as well. It is quite customary to-day for large tracts of land to be granted in concession to individuals or companies engaged in commerce, agriculture, or mining and prospecting. Most of these grants are made by small States or by colonial governments which desire to attract capital and open up their country, and the greater part are located in the scarcely known and unmapped portions of the world. A promoter is often behind these various concessions. He paints a glorious picture of the agricultural, commercial, or mineral advantages which may be investigated, or caused to be investigated, by somebody who wants to buy. These concessions may comprise tracts of from 20 to 20 000 sq. miles. The engineer leaves New York accompanied by perhaps two assistants and armed with a kodak; he returns from 3 to 5 months later with a rough map of the territory, photographs, and sufficient data to demonstrate what is best to do.

While the time of option is usually very limited, there may also be climatic obstacles. For example, in the eastern part of Nicaragua the dry season lasts from 2 to 3 months. In the wet season the trails are absolutely impassable. The mud is knee-deep and neither man, mule, nor ox can travel for any distance. In one of these dry

* Continued from October, 1911, *Proceedings*.

Mr. Millard. seasons, the writer was one of a party of three who made a rough map of 600 sq. miles of mining territory, including a run of 114 miles to the coast to see whether a railroad was "possible." If the work had not been done rapidly, it would have been necessary to wait another year.

A barometer is not an exact instrument, but its daily variation is easily tabulated. The variation due to a "high" or "low" area will not be noticed if spread over a week's traveling of from 10 to 30 miles per day. The barometer is a very valuable and scientific "toy." If it is supplanted by a transit or a level, the survey can no longer be called a mere reconnaissance. In railroad work, the use of these instruments indicates a preliminary, as far as exploration work is concerned.

Reconnaissance work is the rough surveying of areas. If the country is open and clear, one may obtain better results and more quickly than when it is densely wooded or covered with jungle. In mule-back work the trails and accessory territory are plotted at night with interpolations regarding territory not seen.

Reference was made to the progress obtained by using Indians with stadia rods and a hand-level stadia. A progress of 7 miles a day in an open country cannot be compared to from 20 to 30 miles, although the information is more exact. However, in a country like the eastern part of Nicaragua, it would be absolutely impossible, except on the narrow savannah bordering the coast, to use the stadia hand-level. The Indian would literally have to cut his way through the tangled growth of vines, trees, and brush. For reconnaissance work this method is too costly. The ordinary hand-level stadia cannot be read at a distance of more than 500 ft., and the writer is quite sure the limit is 300 ft.

A reconnaissance is made strictly according to the definition of the word. It is not accurate. It is rough, and quickly made, but it must be supplied with copious notes. Naturally, if these are taken by a third member who is capable of figuring (as for a railroad) tonnage for the future, etc., the notes will be as valuable as it is possible for them to be.

Mule-back methods are not the only ones by which reconnaissance work may be done; but mule-back methods do mean a saving of time and money, whether the country surveyed is high, open, low, or covered with brush and timber. It is a method that brings results. Too many parties, leaving the United States for foreign parts, have spent most of their time in building camps and using painstaking methods on a survey which was more adapted to Broadway than to the wilds.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONSTRUCTION OF THE MORENA ROCK FILL DAM, SAN DIEGO COUNTY, CALIFORNIA.

Discussion.*

By M. M. O'Shaughnessy, M. Am. Soc. C. E.

M. M. O'Shaughnessy, M. Am. Soc. C. E. (by letter).—In reply to Mr. Galloway, it may be stated that the paper shows the concrete facing to have been discontinued at the 42-ft. contour, so that the water pressure to which the masonry without concrete facing was subjected was at the 65.33-ft. line, or 23.33 ft., and that the leakage diminished as the pressure of the water increased, due to the compression of the mud and silt in front of the old concrete toe wall, which was constructed of coarse rubble concrete in 1897-1898. The writer notes that in all the recent German masonry dams a layer of clay and soil is deposited on the water face of the masonry. Mr. O'Shaughnessy.

The writer concurs with Mr. Galloway in his objections to the central diaphragm in a rock fill dam, unless such dam is of the cellular type of reinforced concrete, and capable of inspection; then, if leakage occurs, it can be stopped by plugging up some of the leaky cells.

Mr. Galloway alludes to the Relief Dam and his connection with the original designs of that structure. Owing to the location of the bed-rock, it is believed that the original plans recommended by him were not followed out in construction, as it now presents a concave face up stream, which puts the concrete skin in tension instead of compression, and has induced many cracks which have developed serious leakage. This leakage, in time, is bound to wash through the dam the "fine material washed in with water to fill voids," which will cause subsequent settlement and impair the effectiveness of the water-

* Continued from January, 1912, *Proceedings*.

Mr. O'Shaughnessy.

tight face. The writer disapproves of the adoption of sheet steel in the concrete facing, as the adhesion of the concrete to the smooth face of the steel would be questionable, and, with an empty reservoir and no expansion joints, the temperature changes might cause the steel to buckle, thus creating a cavity which might be subjected to hydrostatic pressure, which would be contrary to the "Hydraulic Principle" expounded so clearly by Mr. Dillman.

Soil, silt, and clay were excluded from the mass of the dam, but not quarry "waste," composed of spalls, as alluded to by Mr. Galloway. In fact, there was a shortage of these materials, and, on the hand- and derrick-placed portion of the dam, numerous men with hammers were employed to break off the sharp edges of flat stones, and chink in the cavities with broken rock.

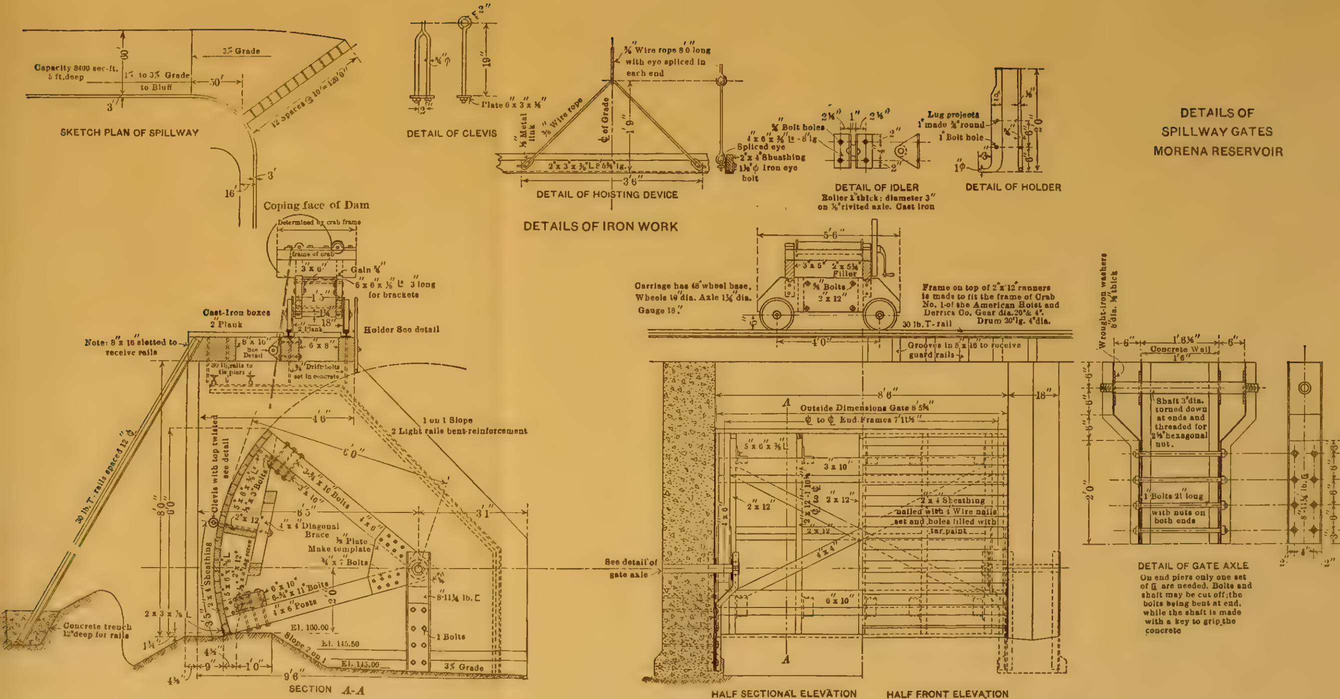
Mr. Galloway's and the writer's views, therefore, agree as to the benefit of using clean quarry waste, free from muck and soil, in the interstices of the dry rubble wall, and his remarks were no doubt caused by lack of clearness in the writer's description.

The spillway will have a capacity of 8 400 sec-ft., and will consist of a channel, 60 ft. wide and 5 ft. deep, on a 3% grade, with an inclined entrance 120 ft. wide, all cut out of the granite mountain side. The excavation for the dam was planned so that the materials from the spillway excavation were not wasted, but were put into the structure. The entrance to the spillway will be controlled by twelve radial gates, 8 ft. 6 in. wide and 6 ft. high, operated by a crab which runs on a track above the gates, as shown on Plate XXIII.

The heaviest floods, measured on the Cottonwood lower down at Barrett, from 250 sq. miles of water-shed, have been about 7 000 sec-ft., and, as the Morena Reservoir has a capacity of 15 000 000 000 gal., for a water-shed of 135 sq. miles, the writer feels secure in the safety of the spillway provisions.

In reply to Mr. Hawgood's further query with regard to the Dulzura Conduit, to which the writer generally referred as being 5 ft. wide and 4 ft. 2 in. deep, with side slopes, etc., a typical section has a top width of 6 ft. 5 in., a bottom width of 3 ft. $1\frac{1}{2}$ in., and a depth of 4 ft. $5\frac{1}{2}$ in. On March 10th, 1911, with a depth of water of 3.3 ft., the wetted perimeter was 15 ft. $8\frac{5}{8}$ in., the water area was 14.335 sq. ft., the hydraulic radius, 0.918 ft., the slope, S, = 0.0008, and the measured discharge over a wier was 40 187 866 gal., which would make n, in Kutter's formula, 0.016, which agrees very closely with previous recognized values of this factor.

As the conduit at present draws water from the Pine and Cottonwood stream beds, and they contain very much fine mica and silt which escapes past the sand and scouring chambers near the entrance and floats along the bottom, the writer never expects it to carry much more than 40 000 000 gal. per day.



DETAILS OF
SPILLWAY GATES
MORENA RESERVOIR

In response to Mr. Maltby's request for further reasons for slope selections on the dam construction: The original water slope was intended to be $1\frac{1}{3}$ horizontal to 1 vertical, by the parties who in 1896 projected this structure, but it only reached as far as the toe wall on the 30-ft. contour in 1898. It was at that time intended to put on a water-tight face of asphalt concrete. Such a face could only survive on a flat slope, and as asphalt with the ultimate evaporation of the volatile oils was not considered by the writer the best material to use for this purpose—for undoubtedly periods will occur when the run-off will not be large enough to fill the reservoir, and the surface of the dam will be exposed to intense summer heat and its consequent destructive influences—this method was abandoned and the present type of water-face adopted. It is apparent that, the nearer the water-face approaches the vertical, the smaller and more economical will be the contents of the dam, so that a slope of $\frac{1}{2}$ horizontal to 1 vertical would be ideal for building a masonry rubble wall. Mr. O'Shaughnessy.

Owing to doubts about the methods adopted in building the old fill behind the toe wall, and the character of this fill, as earth and soil, at the time of that construction, were dumped indiscriminately with rock, parts of which the writer had to remove, he decided to adopt the 9 horizontal to 10 vertical slope up to the 120-ft. contour, and thence to the top the $\frac{1}{2}$ to 1, or preferable, slope.

The base of the old work was started much wider, owing to the intended flatter water slopes, hence the 21-ft. berm on the back at the 100-ft. contour. If the dam is ever raised, through the desire for more capacity, because of the reservoir silting up, or for other reasons, this berm can be well utilized for this purpose, thereby reducing the expense of raising the structure.

The lower slope of all rock fill dams should be $1\frac{1}{2}$ to 1, or about the natural slope of the rock, and a rubble wall, or the hand-placing of the rock in this portion of the dam, as in some structures alluded to in the discussion, is thought by the writer to be an unnecessary expense and refinement, except for esthetic purposes.

As stated in the paper, the reinforced concrete was discontinued at the 42-ft. contour, and the greatest care was taken to make the masonry face tight and of first-class construction from this level to the top, all large face stone being washed with a hose jet before being bedded in the cement mortar, and the latter being tamped into all the joints with iron spoons. The views of Mr. Maltby and the writer are in agreement, therefore, as to the effectiveness of this method of construction, though it is more expensive than the concrete face work.

The object of reinforcing the concrete facing was to prevent cracks, so that each 48-ft. section would be a unit slab, firmly attached to the masonry, but free to move at the joints in response to any temperature or settlement stress. The anchor rods through the masonry form an

Mr. O'Shaughnessy.

effective bond between it and the reinforcing rods, and are also useful in construction operations in fixing accurately the position of the bars.

The apparent excess of steel in the foundation face work is a precautionary measure for the purpose of making an effective bond between the new concrete and the old foundation toe wall of rubble concrete built 12 years ago.

This toe wall was 12 ft. wide at the 30-ft. contour, and 4 ft. from the water face had a slot, 1 ft. wide and 5 ft. deep, into which the grillage of steel bars is nested.

As the work was not completed at the date of writing the paper, the writer refrained from giving the detailed costs desired by Mr. Maltby, and as there are many elements, such as construction roads, telephone lines, insurance costs, interest during construction, etc., which must be computed before the entire cost is obtained, such information might be misleading. Approximate estimates are available, however, which show the cost of a dam of this type in a very favorable light, compared with a masonry dam such as the Roosevelt, in Arizona, which it closely resembles in size, as Table 8 will show.

TABLE 8.—Comparison of Roosevelt and Morena Dams.

	Roosevelt Dam.	Morena Dam.
Height	280 ft.	267 ft.
Thickness of base	170 "	300 "
Thickness of top	16 "	16 "
Crest length	1 080 "	550 "
Contents	340 000 cu. yd.	306 000 cu. yd.
Cost	$3 468 000	$1 100 000
Time consumed in building	4 years.	5 years.

As the writer had much difficulty in procuring any reliable published data describing mass shots, he took advantage of this opportunity to publish the Morena results, in the hope that they might be of interest and value to his brother members.

In connection therewith, it is interesting to note the erroneous ideas which prevailed regarding the costs of structural work in San Diego as late as 16 years ago. The writer quotes verbatim the preliminary estimate, made at that time by a San Diego hydraulic engineer, who has since obtained distinction in his profession even to the extent of writing a book on dams and reservoirs:

"Estimate of the cost of a rock fill dam 125 ft. high, or 5 ft. above the line of 1 000 in. capacity, is about as follows:

"Estimate of Morena Dam, 120 ft., Rock Fill.

"Preparation of foundations, concrete in base and toe walls, etc.	$5 026
Three outlet pipes, laid in trench cut in solid rock and bedded in concrete, with valves, etc.	9 500

Mr. O'Shaughnessy.

160 000 cu. yd. rock fill, 80%, put in place by powder at 10 cents per yard.............	12 000
20%, or 40 000 yd., picked up and placed by rope-way at 40 cents..........................	16 000
6 680 cu. yd. dry rubble wall at $2.50...........	16 700
30 666 cu. ft. asphalt concrete face at 50 cents...	15 333
Spillway and gates, capacity 25 000 cu. ft. per sec.	20 000
Total..................................	$94 559"

While the writer believes that reinforced concrete possesses merits in many locations and for many purposes, he is also a believer in its limitations. The permanency of any structure made of it will depend much on high-class manipulation of the ingredients, as well as thorough proof of the reliability of the cement, and the character of the sand and rock used. The American cement industry has expanded to such an extent in recent years that engineers should observe the greatest caution in using any new or untried brands before time has demonstrated their worth.

The writer believes a reading of the paper and discussion will have developed the following conclusions:

1. That a masonry dam, with a wagon-hauling cost of 1 cent per lb., or $4.00 per bbl. for cement, would have been more expensive than the present structure.
2. That freedom from uplift pressure is a desirable feature in favor of the rock fill type.
3. That the great "Hydraulic Principle" of one impervious surface next to the water pressure, as elucidated by Mr. Dillman, is the object to be obtained by engineers in dam construction.
4. That rock can be excavated economically by mass shots at higher levels above a dam without endangering the site formation, provided the strata are located so that the effects of the explosion will not open seams in the vicinity.
5. That the circular outlet tower of the type designed is the most economical that can be constructed.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROVISION FOR UPLIFT AND ICE PRESSURE IN DESIGNING MASONRY DAMS.

Discussion.*

By Messrs. W. J. Douglas, Lindsay Duncan, and Arthur P. Davis.

W. J. Douglas, M. Am. Soc. C. E. (by letter).—*Uplift.*—It seems rational to disregard uplift if the dam is built on impervious rock, but, even in such case, a cut-off wall, having a depth and width of approximately one-tenth the height of the dam, should be let into the rock at the heel. Further, the line of pressure, under maximum water-load conditions, should lie well within the middle-third. Mr. Douglas.

The experiments made by Ottley and Brightmore† indicate the probability that there is a greater tendency toward tension at the heel of a masonry dam than is indicated by the common straight-line distribution of pressure, which ignores the elasticity of the material. If, therefore, a dam is designed so that the line of pressure is practically at the limit of the middle-third, there may be a tendency for tension at the heel which the masonry is incapable of transmitting to the foundation. In this case, the bed joint would open, and actual uplift would take place. Based on the experiments referred to, the writer would suggest a slight batter at the back of a dam, say 1 to 12, extending from the lower third point to the base. This masony would be added to the theoretically determined section, the line of pressure in which was at or near the limit of the middle-third.

In regard to the question of the probable imperviousness of rock, the designer is often forced to assume, on the basis of borings or test pits, that the entire dam site, when stripped, will be in accordance with the small area explored, but this is frequently incorrect. If the

* Continued from February, 1912, *Proceedings*.

† *Minutes of Proceedings*, Inst. C. E., 1908.

Mr. Douglas. designer assumes no uplift, it is incumbent on him to verify the safety of such an assumption by observation of the uncovered foundation bed.

The suggested back batter, in conjunction with a reasonably deep cut-off wall, is all that is necessary to guard against uplift under a dam resting on an impervious foundation, provided the foundation is properly cleaned and the masonry well bonded to it. It should be borne in mind, however, that in all gravity dam design engineers are working with a comparatively low factor of safety, and this is justifiable only when the conditions are known with a high degree of precision. In the case of a gravity dam, even on an impervious bottom, the designer is forced to assume a unit weight of the material and a distribution of the stresses, neither of which is quite correct, and, for this reason, if the suggested back batter is omitted, the line of pressure under maximum water-load conditions should lie well within the middle-third.

If the foundation bed is pervious, every effort, of course, should be made to stop seepage, or flow of water, by the construction of a cut-off wall carried down to impervious material; and adequate drains should be provided below (down stream from) the heel, so that any water passing the cut-off wall may be carried off without causing material uplift. The intensity of this uplift depends entirely on the resistance which the water meets after it enters below the dam and before its free discharge there. If the water meets with no resistance, there is no uplift; whereas, if there were no drains, and if a second cut-off wall were provided at the down-stream toe, and this latter wall were carried to an impervious bed, the entire base of the dam might be subjected to an uplift equal to the full hydrostatic head. It is desirable, therefore, not to have a toe cut-off wall unless it is imperative, as in the case of a spillway section; and, when this is so, this wall should not be carried down to impervious strata, unless in the design of the dam full uplift has been considered over its entire base.

If the cut-off wall at the heel cannot be carried down to impervious strata, the designer would best assume full uplift at the heel and zero at the toe. This is only necessary when the foundation bed is generally pervious, as occasional springs can be cared for by drainage or possibly by grouting. In reference to this matter, however, it might be well to keep in mind the fact that precautions which may be ample to care for springs under practically no head, prior to the dam construction, may be entirely inadequate under a high head.

In regard to the construction of a gravity dam on a bed which is so porous that it might transfer full hydrostatic head for the full area of the base, and where cut-off walls cannot be constructed to sufficient depth to decrease this head materially, it seems that such a site is unsafe for a gravity section, whereas the buttress and the hollow concrete dam offer types particularly advantageous under such conditions.

Mr. Douglas.

The buttress type is desirable when the dam is to rest on pervious rock of sufficient strength to withstand the concentrated pressures brought by the buttresses. The hollow reinforced concrete dam would best be used where the ground is pervious and too soft to carry the heavy pressures which would be brought on it by the gravity dam and more particularly by a buttressed one.

In regard to uplift within the masonry itself, there is no doubt that, in even the most compact and impervious masonry, there is a certain amount of it, but as thin reinforced concrete slabs of hollow dams are withstanding high heads without even moisture on the under side, it seems highly improbable that, in a well-built gravity dam, uplift need be taken into consideration. In a badly constructed dam, or in one in which improper materials are used, full uplift might occur at the heel of any section with zero uplift pressure at the toe. To assume full uplift at the toe would be to assume that the masonry there was absolutely impervious, whereas the masonry in the remainder of the dam was highly pervious. This seems to be an impossible condition.

Although somewhat outside the scope of this paper, the writer would like to invite attention to the so-called "economical profile" which, 50 or 75 years ago, was evolved by able engineers with mathematical inclinations. These profiles, based largely on maximum allowable pressures, are no longer of value except as traditions, yet they often appear in technical books as examples worthy of emulation. Attention is called to these obsolete profiles because they are unnecessarily confusing to the beginner.

Ice Pressure.—It is difficult to understand how quiescent ice produces material pressure on the back of a dam, except in certain sporadic cases which will be referred to subsequently. It appears that the basis of the somewhat common belief in such pressure came from knowledge of the destructive power of ice in motion. It is evident that an extensive area of sheet ice in motion would exert a pressure on the side of a river pier, which might approximate its crushing strength, which varies between 100 and 1 000 lb. per sq. in., depending on the purity of the water and the method of ice formation. It is on record that piers have been moved out of line and out of plumb, and that at least one bridge pier was raised bodily off its foundation, due to the adhesion of sheet ice in conjunction with a rise in the water level, but such destructive action has nothing to do with the pressure of quiescent ice.

Ice forms at a temperature of 32° Fahr., and, as the temperature falls, it shrinks and cracks. The cracks fill up with ice, in whole or part, and new ones are formed. Large areas of ice under a rise of temperature expand, pushing up into hummocks and thereby relieving the pressure, or, if the shores are sloping, it finds relief by sliding up

Mr. Douglas.

the banks. At an overflowing spillway the water does not freeze against the dam. In a reservoir dam the ice freezes to the dam, and, if the water rises or falls after the ice is formed, the latter bends and breaks without much strain on the dam, as it is both brittle and low in tensile strength.

Recently, on a forebay dam, where there is a daily fluctuation in the water level, it was found, on examination, that the upper surface of the ice was 1 ft. thick; under it there was 1 ft. of water and under that $1\frac{1}{2}$ ft. of ice. That was as far as the examination was carried, or at least as far as the writer has knowledge of it, and it is cited in the hope that others who are interested will supply additional information on the subject of pond ice, on which little has been written.

There are certain conditions under which quiescent ice is dangerous to the stability of a dam. If the ice is thick, and the adjacent banks are only a few hundred feet away and are vertical, or nearly so, the ice in expanding might exert material pressure, but even in this case it is doubtful if it would be great, unless the banks were of unyielding material, such as rock, and the water fluctuated in level. The Minneapolis dam failure offers a case of this kind. Ice several feet thick formed back of the dam, and the water was then drawn off. The ice sagged, forming an inverted arch with the dam for one abutment and the shore for the other. The water subsequently rose and through arch action pushed the dam out of plumb. If there are other records of sheet ice pushing dams out of normal, it would be interesting to have them recorded in the discussion of this paper. The writer recalls one or two cases in which it was a matter of doubt whether or not the ice was an active agent, but none seemed to point clearly to it as a direct cause of failure.

TABLE 4.—EFFECT OF ASSUMED ICE PRESSURE AND UPLIFT ON DAM DESIGN.

The width of the base of the dam is given in feet.

Conditions.	Height of Dam.					
	5 ft.	10 ft.	30 ft.	60 ft.	100 ft.	250 ft.
Water pressure only	3.2	6.4	19	40	65	161
With ice pressure at 43 000 lb. per lin. ft.	41.6	41.9	45.8	56.7	76.7	167
With full uplift at heel, diminishing to zero at the toe	4.2	8.4	25	51	84	211
With above ice pressure and uplift	54.5	55.0	60	74	101	218

For simplicity of computation the top width of the dam is assumed to be 0.

In regard to the often quoted 43 000 lb. per lin. ft. of dam specified by the Quaker Bridge Commission, it might be well if engineers would

discontinue reference to this fact as having a bearing on the subject of general dam design. It is generally admitted that this pressure is conservative, and that at the time it was a wise precaution, but the writer does not believe it to be advisable to offer it now as a basis of dam design. Table 4 shows the effect of ice pressure on dam design, assuming 43 000 lb. per lin. ft.; and also the effect of uplift, assuming the full head at the heel and zero at the toe. Mr. Douglas.

Lindsay Duncan, M. Am. Soc. C. E. (by letter).—In February, 1906, the writer visited the Lake Cheesman Dam, of the Denver Union Water Company, with George T. Prince, M. Am. Soc. C. E., Chief Engineer, in order to observe the effect, if any, of the ice pressure on the dam. Mr. Duncan.

At that time the reservoir level was 30 ft. below the spillway, and the ice was 12 in. thick. The days were warm and the nights cold, the maximum and minimum temperatures being about 50° and 20° Fahr., respectively, and the conditions, apparently, were favorable for ice thrust.

The writer was unable to detect any crushing or folding of the ice, but found that the portion directly against the masonry of the dam had softened and partly melted. It was evident that the masonry was at a temperature higher than the freezing point of water, and transmitted sufficient heat units to thaw the ice in contact.

This may possibly be the reason that engineers have no record of failure of a masonry dam on account of ice pressure.

Arthur P. Davis, M. Am. Soc. C. E. (by letter).—The main principles on which to base the design of a gravity dam for the resistance of uplift and ice pressure are given by the author with a conciseness and brevity rarely equalled. Mr. Davis.

For the reasons stated, the pressure of ice need seldom be considered; but, when there is a possibility that maximum ice pressure may be attained at the time the reservoir is full, it becomes important, because it is exerted near the top of the dam, at the time when both the water pressure and the uplift are also at their maximum, and when low temperatures have a tendency to open vertical cracks and allow the water to enter the dam and thus obtain access to horizontal joints which might not otherwise be reached.

The determination of the perviousness of natural formations is one of the most difficult things in Nature. Any examination of such formations which disturbs them, changes the conditions which it is desired to know. For this reason, it is necessary to allow a large factor of safety in any estimates which involve this factor.

In general, it may be said that water will more readily follow seams or bedding planes than devious paths through the material of the rock. It follows that it will pass more readily and in larger volume

Mr. Davis. in the direction of stratification than in a direction normal thereto. Similarly, stratified rock will permit percolation more easily and in greater volume than good, massive rock, such as granite.

Granular rock, such as sandstone, is likely to transmit more water through the rock itself than one of denser or finer grain, such as limestone or shale, but no exact rule of this nature can be laid down, because there are many varieties of each kind of rock, with various percolating capacities. In general, however, the following rules may be taken as a rough guide:

1. Massive or crystalline rocks, such as granite, gneiss and schists, will transmit water less freely than those of sedimentary origin.

2. Stratified rocks will transmit water much more readily in the direction of stratification than transverse thereto.

3. In the direction normal to stratification, sandstone will generally transmit water more readily than limestone, and the latter more readily than shale.

4. Stratification on a plane approximately horizontal is the worst possible condition for introducing upward pressures beneath a dam. Conversely, the most favorable position in this respect for stratified rock is in vertical beds.

An eminent geologist has stated that "it is safe to say that no foundation is entirely impervious." This may be too strong a statement, but at least it is unsafe to assume that any foundation is entirely impervious. If this is true, it follows that some provision for uplift should be made in the design of every masonry dam. This uplift may vary from a negligible quantity to the full hydrostatic head under an entire horizontal joint in the foundation. The amount of this force cannot possibly be foreseen with accuracy, and under ordinary circumstances cannot be foretold within rather wide limits; its estimation requires thorough investigation and the exercise of the highest degree of skill enlightened by the greatest available experience.

If the dam must be built as a purely gravity structure on a straight plan, the most economical method of meeting this problem is by increasing the batter on the water side of the original gravity structure, such increase of batter to depend on the amount of uplift to be provided against. For dams of moderate height, the greatest safety with a given quantity of masonry is attained by a section roughly conforming to a right-angled triangle with the hypotenuse on the water slope. This form enlists the weight of the water to assist in holding the dam in place, and the increase of the batter may be carried to such a point that this resistance overbalances the tendency of the water to push the dam down stream.

The reason this principle is inapplicable in so many cases is that the average low masonry dam must serve as a spillway, and the impact of a large volume of water at the down-stream toe would be

Mr. Davis.

dangerous. Therefore, it becomes necessary to carry the masonry on such a slope as will prevent this impact and carry the water quietly away from the dam, allowing it to expend the accumulated energy in friction on the river bed at some distance below. This usually requires enough masonry to fulfill gravity requirements, without much batter on the back. The form described also has limits due to the height of the dam when the pressures at the down-stream toe approach the safe limits on the foundation. These limits vary widely with different foundations, and their determination in advance is so uncertain that a large factor of safetly must often be allowed.

Where conditions permit, one of the surest and cheapest methods of providing the extra factor of safety required by the important and uncertain factors under consideration is to build the dam on a curve, arched up stream. If this be done, there is no possibility of its sliding or overturning without crushing either the masonry or its abutments. Any form of masonry is well adapted to the resistance of compressive strains, and it is on this that reliance should be placed when feasible.

The most frequent objection to such a proposition is that the compressive strains on the voussoirs of the arch and the rock of the abutments would be greater than safety would permit. Such a statement is usually based on the assumption that all the strains are taken by the arch and transmitted to the abutments. Such a result is absolutely impossible of attainment. It is impossible to deprive the dam of its weight; any properly built dam has resistance as a cantilever, irrespective of its plan, and no strains can be transmitted by the arch to the abutments until the resistance due to gravity and shear have been brought into play. The arch can only be made to take the residue, and if large strains are transmitted to the abutment this only confirms the necessity of the curve plan. If they are not so transmitted, and the dam resists all pressure by its weight, then the objection to the arch form is simply the increased cost.

To cite a concrete example, now fresh in the minds of all engineers: If the dam above Austin, Pa., had been built on even a very slight curve, without any more masonry, it would be standing to-day. The length of this dam has been differently stated, but may be assumed as 400 ft. Had the dam been built on a circular plan of 400 ft. radius, with the same section, it would have contained about 5% more material and the pressure against it would have been about 5% greater, due to the greater surface exposed to water pressure.

The reservoir was filled in 1910 and stood for many hours in this condition, and, though it failed by cracking and sliding slightly on its base, the failure was neither sudden nor complete. This shows that, though the stresses were beyond its power of resistance, the excess was not great, and was probably less than 10 per cent. Let it be as-

Mr. Davis.

sumed that this excess was 10 per cent. If, therefore, these stresses had been increased by 5%, and the powers of resistance had been increased by 15%, the dam would have stood. Had there been doubt of the ability of the rock to take such a pressure, this could have been reduced to any desired amount by spreading the abutments and distributing the pressure over a larger area. That is, the stresses transmitted to the abutments would be only those above the resisting forces, considering the dam as a gravity structure.

Recent experience has shown the feasibility and efficacy, in some cases, of closing the crevices in the foundations wholly or partly by grouting them under pressure. This was accomplished successfully at moderate cost on the Ashokan Dam, and on several others of recent construction. The most striking instance of this kind which has come to the writer's attention is the Clackamas Dam, in Oregon, which was built on a foundation of semi-indurated volcanic ash, which was checkered in all directions by innumerable fissures, and, furthermore, was so soft that percolation was likely to cause destructive erosion. A triple line of holes was grouted along the up-stream toe of this dam, and recent information is that, since the dam has been in use, no perceptible percolation has taken place.

The effect of such grouting is not easy to foretell, and, like all other underground conditions, must be estimated with extreme caution.

Supplementary to this grouting process, a system of drains may be placed in the foundation, or in the masonry near the water face of the dam, which can be made to collect any waters percolating under high pressure and carry them harmlessly to the river bed below the dam.

An intelligent application of any or all of these remedies will make it unnecessary under any circumstances to provide otherwise for full upward pressure under any entire horizontal joint or plane.

It cannot be too strongly emphasized that no fixed rules, or "rule-of-thumb" method, can be adopted for the design of high masonry dams. Every dam of that kind is a problem unto itself, requiring the highest degree of skill and judgment for its correct solution; only the general principles and their nature can be set down in advance.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

NOTES ON A TUNNEL SURVEY.
Discussion.*

By Messrs. George D. Snyder, B. F. Cresson, Jr., Robert Ridgway, and S. M. Purdy.

George D. Snyder, M. Am. Soc. C. E.—This paper forms an interesting contribution to the literature of a class of underground surveying on which very little has been published. Mr. Snyder.

The object of such a survey, of course, is to fix the location of the tunnel accurately, and then to give the workmen sufficient information to enable them to build it in the pre-determined position, and also to enable the relation between points or objects on the surface and points underground to be determined. In this case the subaqueous tunnel forming part of a longer underground railway, it was also desired to extend the continuous stationing of the land tunnels across the river; but the desire to ascertain this distance was not the only object in making a triangulation survey, nor was it necessary or necessarily advantageous to have any particular tangent intersect the base line at a triangulation point. All that was requisite was to connect the triangulation system with the land surveys by any convenient method, and then, by the aid of co-ordinates, to compute the length across the river on the center line of either tunnel.

In the description of the triangulation system, the paper refers to co-ordinates, but it is not clear that they were used throughout the underground surveys. The use of co-ordinates facilitates the computation so much, in the determination of the relations between points on the surface and underground, and in the determination of the objective in driving, that attention should be called to the fact in such a paper.

*This discussion (of the paper by Frederick C. Noble, M. Am. Soc. C. E., published in *Proceedings* for December, 1911, and presented at the meeting of February 7th, 1912), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Snyder. When a tunnel is to be driven in a straight line, on a level or slight grade, between shafts which are in view of each other, no elaborate or precise triangulation system is necessary, as the line on the surface between shafts can be transferred underground and projected ahead without having the exact distance between shafts, and this can be determined accurately enough for all practical purposes by a very simple triangulation. However, where curves are used, and where the shafts cannot be located on the axis of the tunnels, or where obstructions prevent a line of sight between shafts, a more or less precise triangulation survey becomes necessary.

The tunnels of the Hudson and Manhattan Railroad having been constructed contemporaneously with the Battery tunnels, some description of the survey methods followed on that railroad may prove of interest. This system consists of about 17 miles of underground railway (measured as single track), of which 12.4 miles are in driven tunnel, including four single tunnels crossing the Hudson River.

When the present company started construction in 1902, the work already done by the old company on the up-town tunnels opposite the foot of Morton Street, Manhattan, consisted of shafts on each side of the river, 3 916 ft. of the north tunnel constructed from the New Jersey side and 160 ft. from the New York side, and 570 ft. of the south tunnel built from the New Jersey side. The south tunnel, the work on the New York side, and 2 000 ft. of the north tunnel, were lined with brick. The remainder of the north tunnel was lined with cast iron with a shield.

The first work done was the completion of the river tunnels, which were driven entirely from the New Jersey side. A base line was measured on the New Jersey side, with a triangulation tower at each end, the relation of the two shafts was found, the position of the old work was located by underground surveys, and the azimuth of a line from the old shield to the objective on the New York side was obtained.

As the work progressed it was felt that there would be more confidence in the accuracy of the surveys if a more careful triangulation was made. Therefore the triangulation system indicated by the points, *Y*, *X*, and *W*, Plate XXIV, was selected, and a base was measured along West Street on the New York side.

In the meantime surveys were under way for the down-town system of tunnels, the triangulation system being indicated by the points, 1, 2, 3, and 4, Plate XXIV. When the construction of these tunnels was authorized, the two triangulation systems were connected by a precise traverse survey indicated by the Points, *A*, *B*, and *C*, and a common system of co-ordinates was established, the origin being 2 000 ft. south of Point 5 and 8 000 ft. west of a meridian passing through this point, this meridian being approximately north.


HOBOKEN
JERSEY CITY
HUDSON RIVER
MANHATTAN
To Newark
PORTAL
D. L. & W. R. R.
ERIE R. R.
P. R. R.
SHAFT A
SHAFT B
SHAFT C
SHAFT D
POWER HOUSE
SOUTH TOWER
JARVIS
CAISSON NO. 3
BASE LINE FOR FUTURE WORK
BULKHEAD
PIERHEAD
STATE LINE
Pier 29
Desbrosses St.
Vestry St.
Harrison St.
Jay St.
Pier 14
Pier 18
TRINITY CHURCH
BERGEN DUTCH REF'D CHURCH
Pavonia Ave.
0 500 1000 2000
SCALE OF FEET

The fundamental base for the up-town system was between Points *X* and *W*. Both these points being on top of buildings, the direct measurement of the distance between them was not practicable, but the measured base being on West Street, and approximately parallel, the relation of the triangulation points was obtained by turning angles to the triangulation points from points on a short base at the ends of the main base line. Mr. Snyder.

The fundamental base for the down-town system was between Points 1 and 3, which were placed so that direct measurement could be made. A check base line was measured on the Jersey City side between Points 2 and 4. The ends of these base lines, as well as intermediate points, were marked by concrete monuments in which were embedded brass plugs with hair-line crosses. The length of the base line between Points 1 and 3 was 3 633.4 ft., and the longest sight in the entire system was 8 246.8 ft. Azimuth increased clockwise from the south point throughout the 360° of arc.

The transits were similar to those used by Mr. Noble, with 6¼-in. horizontal circles, reading to 20″, although some 7½- and 8-in. instruments, reading to 10″, were used. There was a difference in regard to the cross-wires, however, for, instead of having a vertical wire, there were two wires forming an angle of about 70° and intersecting slightly above the horizontal wire. The advantage of this arrangement is that the diagonal wires do not cover the plumb-lines which are used for sights. Inverting telescopes with large 1½-in. object glasses were used. The instruments had three leveling screws.

The base lines were measured as follows: Steel tapes 100 ft. long were used, and were compared with a tape which had been standardized by the United States Bureau of Standards. The line was prepared by marking points at intervals of about 98 ft., and at least two lines of levels were run over these points. Heavy movable spiders, Fig. 1, Plate XXV, having a hair-line cross cut on the brass head, were then placed at these points, four being used in succession. The tape was then stretched between the spiders. One end was clamped to a weighted standard and the other end was given a pull by a 12-lb. weight attached to a cord passing over a ball-bearing pulley. The tape was supported at intervals of about 20 ft., these intermediate supports being set to a uniform grade between adjacent spiders. Readings were taken simultaneously at each end, and the difference gave the distance between the spiders. Ten observations were made, and after each reading the position of the tape at the spiders was changed longitudinally. Measuring with a rule the distances of the tops of the spiders above the points on which elevations had been taken, enabled the inclination of the tape to be determined, from which the horizontal equivalent was obtained. Each base line distance was the corrected mean of at least three such measurements. The observed distances were also cor-

Mr. Snyder. rected for temperature and for the constant errors of the tape. All measurements were taken at night, so as to avoid traffic difficulties and have more uniform temperature conditions.

The main triangulation angles were repeated at least 40 times, readings being made on the tenth repetition, and the telescope reversed after each successive ten repetitions.

Angles in the primary triangulation were first adjusted by the rigid method, according to Johnson. It was afterward considered that the base lines had less likelihood of error than the angles and a second adjustment was made so that identical results could be obtained in computing the sides of the triangles from either base of the quadrilateral.

As these tunnels form part of an interstate railroad, it was necessary to determine the portions in each State. The State line is approximately in the center of the river, having been established definitely by a Joint State Commission and referred to prominent objects on the shore, such as Trinity Church spire and the Bergen Dutch Reformed Church, which were also points of reference of the United States Coast and Geodetic Survey. These points, therefore, were located by angles from the triangulation points, which enabled the co-ordinates of these points and points on the State line to be determined, and from which intersections with the tunnels were computed. In like manner, the reference points of the harbor bulkhead and pierhead lines were located, so that their points of intersection with the tunnel could be determined.

The Hudson and Manhattan Railroad Company contemplates building in the future another pair of tubes across the river, and has already built short lengths of these tunnels on Cortlandt and Fulton Streets and at points where these tunnels cross under the Fulton Street tube, and certain junction enlargements on the New Jersey side. When this work is undertaken it will be necessary to drive the tunnels from new shafts, the position of which will then be determined, probably on the New Jersey side, and the objective will be these short lengths of tunnels and junctions already completed. It will then be necessary to determine the position of these new shafts with reference to the completed work. It was felt that it would not be safe to rely on the monuments of the triangulation, as they are likely to be disturbed, and that more permanent points should be established on property within the control of the Company, as a basis for this future work. Therefore, two precise points within view of each other have been established and their co-ordinates determined, one being on the main power-house and the other on the elevator shaft-house of the Pavonia Avenue (Erie) Station in Jersey City (Plate XXIV).

The lines were transferred underground in the ordinary way by plumb-lines at the shafts (Fig. 4). This was made somewhat diffi-

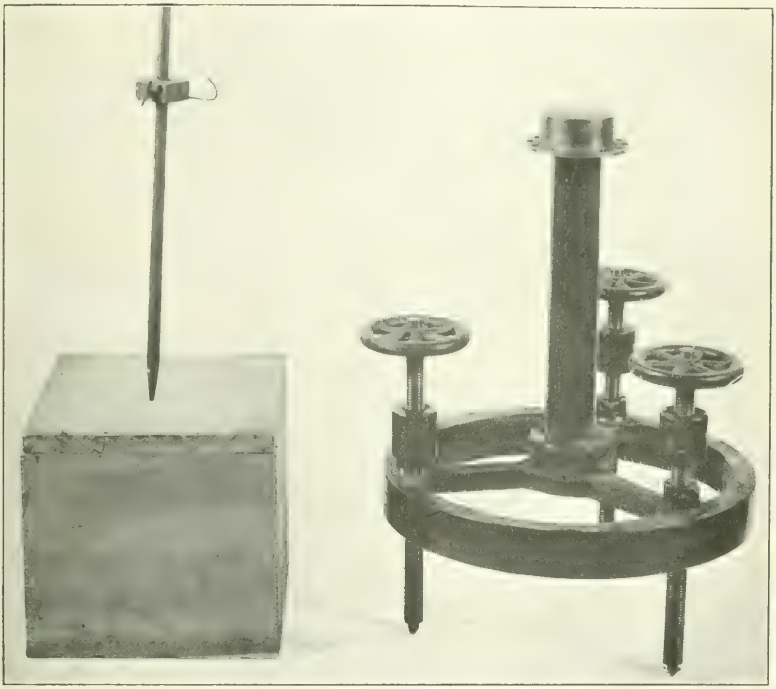


FIG. 1.—PICKET USED FOR INTERMEDIATE SUPPORT OF TAPE; AND SPIDER USED IN MEASURING BASE LINES.

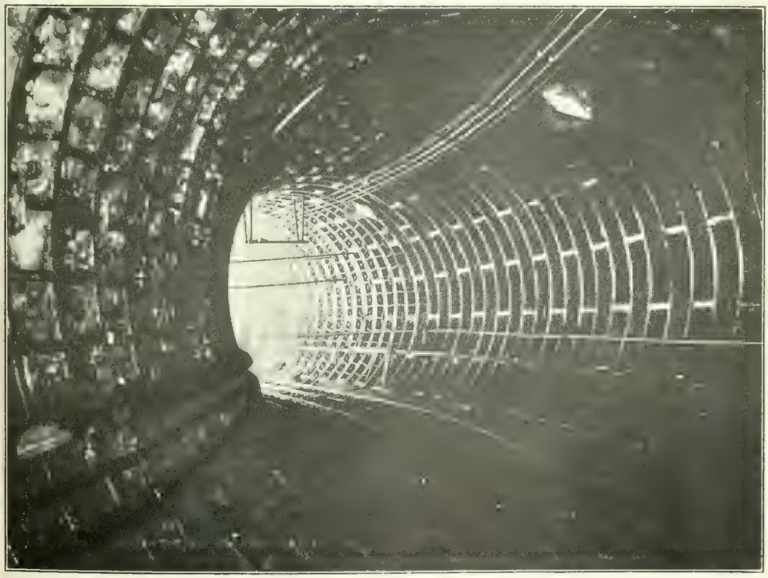


FIG. 2.—TUNNEL ON CURVE, WITH SUPPORTS FOR TRANSIT AND OBSERVER HUNG FROM ROOF.

cult on account of the small size of some of the shafts and the fact that some of them were placed to one side of the tunnels. The Morton Street shaft (New York City) was only 7 ft. in diameter, and was placed between the tunnels, so that the direction of the line transferred was at right angles to the tunnels instead of parallel to them. The Pier *C* shaft (Jersey City) was located more than 100 ft. south of the nearest tube. At Cortlandt and Fulton Streets, New York City, the shields were started in chambers sunk in the form of caissons from the surface, and the lines were transferred by the use of two plummet wires lowered from the surface through pipes extending through the roof. In all these cases where the plumb wires were close, the position of the surveys was checked by plumb-lines in pipes driven from the surface 200 ft. or more from the initial point, so as to get the advantage of a longer base. Alignment scales, similar to those Mr. Snyder.

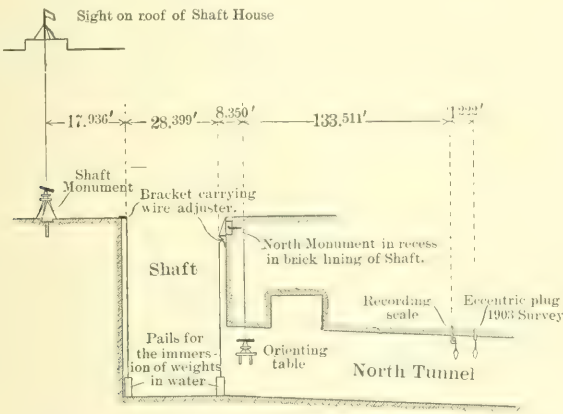


FIG. 4.

described by Mr. Noble, were used in ranging in the line at the shafts, but not elsewhere. The position of the line underground was the average of a large number of observations; at the 15th Street shaft (Jersey City) the first angle from the underground base was the mean of more than 400 observations. Lines were transferred underground at twelve points.

In the underground surveys two general methods were followed: the preliminary and the final. The preliminary lines were kept close to the face, for the proper guidance of the workmen. Owing to the movement of the iron lining for some distance back of the shields, due to the thrust of the rams and other causes, it was necessary to follow up and keep correcting this preliminary work with more precise surveys carried forward from points in the portion of the tunnel which had come to rest. In driving the shield through the silt without excavating, the tendency of the iron lining was to rise immediately

Mr. Snyder.

in the rear of the shield and then gradually to come to rest. The maximum rise was about 1 in. at a point about 30 ft. in rear of the shield, and the iron would then gradually fall 3 or 4 in. below its original position. A shield being driven alongside a tunnel previously built would cause a slight lateral movement in the latter.

In the preliminary method all distances were measured at least twice, the tape being given a uniform pull of 12 lb., with a spring balance and without intermediate supports. Angles were repeated six times.

The final measurements in the underground work were carried on by methods similar to those used in the base line measurements on the surface, excepting that the spiders were not used, measurement being made to points plumbed down from the roof. The tape was supported on blocks at intervals of 20 ft., and the pull was obtained by a spring balance.

The method of prolonging or extending the lines differed from that used by Mr. Noble, it being to set a point ahead approximately on line and then to obtain its position by measurement of the distance and the exterior angles from the points in the rear. Similarly, in extending the lines through a lock, the projection of a straight line was not attempted, but a point in the lock was occupied by the instrument, and the angle to points on either side was obtained by repetition.

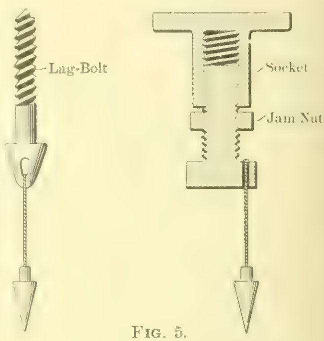


FIG. 5.

The underground points were marked by small lag-bolts having flattened heads and a pointed hole so that a plumb-line would always take the same position. These were driven into strips of wood clamped to the tunnel bolts (Fig. 5).

Very important points, or where it was necessary to set points on a definite line, were marked by eccentric plugs (Fig. 5). These plugs, with sockets, were set approximately in line, and fastened rigidly to the tunnel structure. A fine hole for attaching a plumb-line was drilled near the rim of the head of the plug. The plug was then turned until the plummet hung exactly in line, and was then fixed in position by the jam nut.

Plummet lamps were not used in the underground work, but sights were taken to plummet lines which were made visible by holding in the rear a light screened by a frame of tracing cloth.

Some of the triangulation angles were turned at night, the sight rods being 1¼ in. in diameter and placed in front of 400-c.p. lamps, screened by a 30 by 40-in. sheet of tracing cloth.

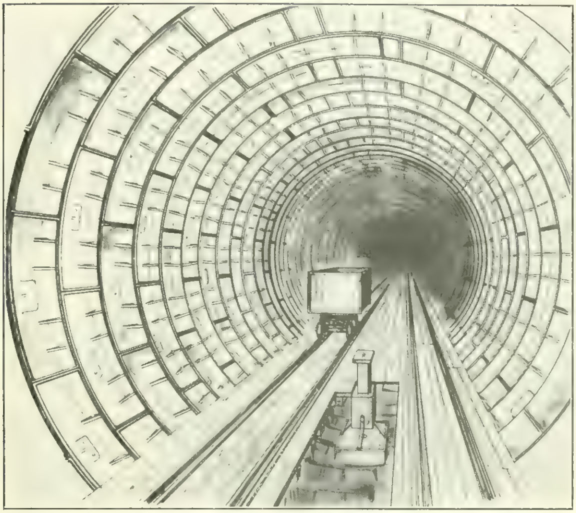


FIG. 1.—TELESCOPING STATION MARK IN FLOOR OF TUNNEL.

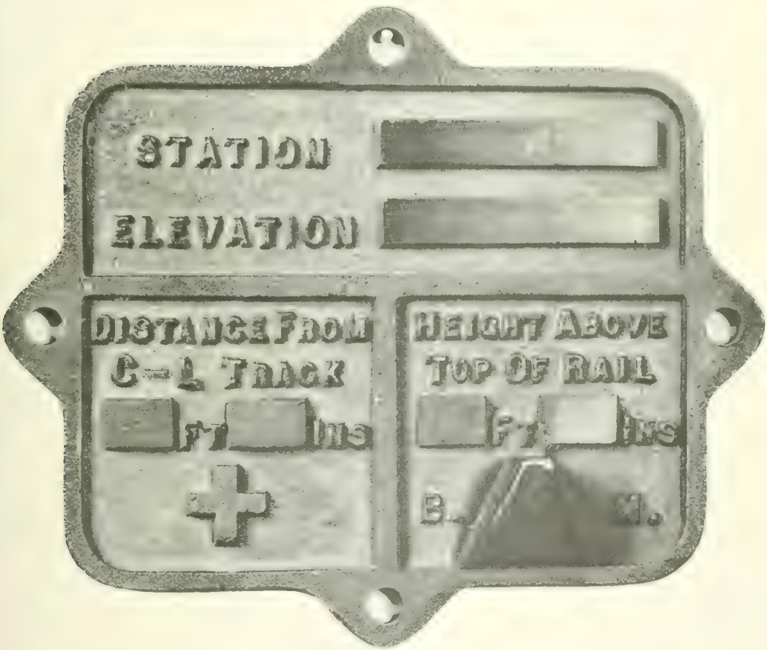


FIG. 2.—REFERENCE PLATES SET IN SIDE OF TUNNEL, FOR USE IN LINING AND SURFACING.

Mr. Snyder.

The method of suspending the transit and observer from the tunnel roof is indicated in Fig. 2, Plate XXV. An adjustable standard for the support of the transit for use at points which had to be used frequently, and which was telescoped to below the construction platform when out of use, is indicated in Fig. 1, Plate XXVI.

For guidance in driving the shield, the construction force was given somewhat more information than on Mr. Noble's work. This consisted of: First, the position of the center of the last ring with reference to the theoretical axis of the tunnel, both in plan and elevation; that is, its position to right or left of the true center line and above or below the true grade line; second, the position of the face of the last ring referred to a plane normal to the theoretical axis of the tunnel; and third, similar information fixing the positions of the shield. In addition, the diameter of the tunnel was measured horizontally, vertically and diagonally, at angles of 45° from the vertical, in order to detect any tendency to distortion. This information was posted on a board at the face and also reported to the construction office on a prepared blank.

The position of the tunnel was usually checked daily at noon, but when unusual progress was being made, it was also checked at midnight, and on sharp curves sometimes every ring was checked.

The original leveling across the river was done by the use of tide gauges, but after the completion of the north tunnel, the levels were corrected by running through this tunnel.

Table 1 gives closing errors of a few of the longest portions of tunnel driven.

TABLE 1.—Closing Errors of Longer Portions of Hudson and Manhattan Railroad Tunnels.

Shaft.	Depth, in feet.	Distance between plumb-lines, in feet.	Length of initial under-ground base line, in feet.	Longest heading driven from shaft, in feet.	Closing error in line, in feet.	Closing error in grade, in feet.
Morton St.	65	5.4	205.7	4 524.1	No check.	No check.
Fifteenth St.	54	27.4	115.8	5 703.7	0.262	0.028
Washington St.	53.8	34.3	58.5	3 379.0	0.025	0.073
Pier C	83	277.4	261.0	5 240.0	0.164	0.004
Terminal	20	31.7	31.7	1 056.8		

The lines run from Morton Street to Twelfth Street and Sixth Avenue could not be checked, as the surface points had been disturbed at the time the shields were holed through.

Table 1 gives the results on only a few of the longer lines. In all, 23 headings were holed through in prosecuting the work. Some of the tunnels were shield-driven, with an iron lining, and some concrete-lined

Mr. Snyder. without a shield, and 19 shields were required. The tunnel built with each shield is indicated on Plate XXIV. With the exception of the old north tunnel, the maximum closing error was $3\frac{1}{8}$ in. for line and $\frac{7}{8}$ in. for grade, but most of the errors of grade have been less than $\frac{3}{8}$ in.

After the completion of the tunnels it was necessary to readjust the line and grade of the track on account of irregularities in driving, and reference plates were set in the sides of the tunnel for use in lining and surfacing (Fig. 2, Plate XXVI).

The original re-surveys of the old tunnel work were made by B. F. Cresson, Jr., M. Am. Soc. C. E. On the commencement of the construction work, the surveys were in charge of Ernest Statham, Resident Engineer. The surveys for the holing through of the old north tunnel, the first to cross the river, were made by the late E. Elbert Young, Assoc. M. Am. Soc. C. E., Engineer of Alignment. When the work was expanded and required a greater force, it was under the direction of two Division Engineers: F. K. Hilt and A. R. Archer, Assoc. M. Am. Soc. C. E.

The writer is indebted to the above, as much of the information in this discussion has been derived from their notes and records.

Mr. Cresson. B. F. Cresson, Jr., M. Am. Soc. C. E.—This paper is exceedingly interesting and valuable as a description of work done. It seems unfortunate that, notwithstanding all the surveys for tunnels and bridges which have been made in the vicinity of New York, very little has been written as to field methods and calculations, or the results obtained in the actual work. If a more thorough description of methods and calculations were to be written, it would be of benefit to those having charge of similar surveys in the future.

The speaker, as Alignment Engineer on the North River Division of the Pennsylvania Tunnel work, had charge of the surveys, triangulations, and calculations extending from the east side of Ninth Avenue to the portal at the west side of Bergen Hill.

Mr. Noble refers to measuring his base lines with a short tape and plumb-bobs. The method used in the Pennsylvania survey was quite different, and was devised with the idea of eliminating almost entirely the use of the plumb-bob for this purpose, as it appears that this instrument is not usually capable of securing great accuracy in results. The speaker used a 100-ft. steel tape, the coefficient of which had been determined. This tape was supported every 20 ft., under a tension of 12 lb., attained by a weight operating over a wheel, and measurements were taken between movable station points placed usually about 99 ft. apart, the tape just touching the brass tops of the movable station points, on which were scratched fine cross-marks. The temperature was taken during each measurement, and the inclination

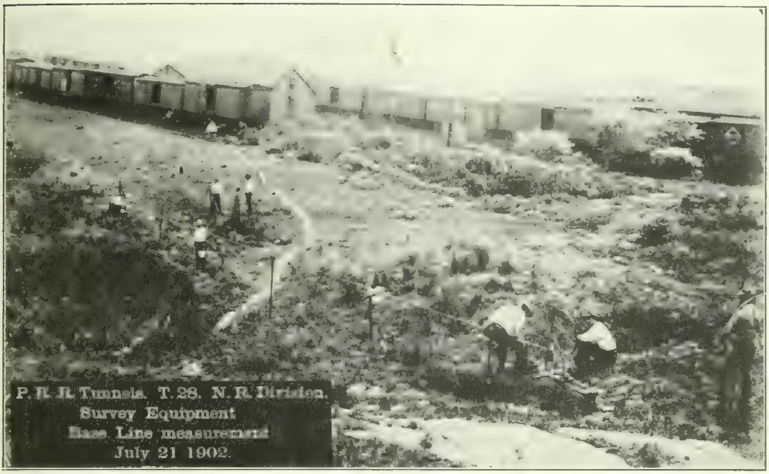


FIG. 1.—BASE LINE MEASUREMENT. PENNSYLVANIA RAILROAD TUNNELS.

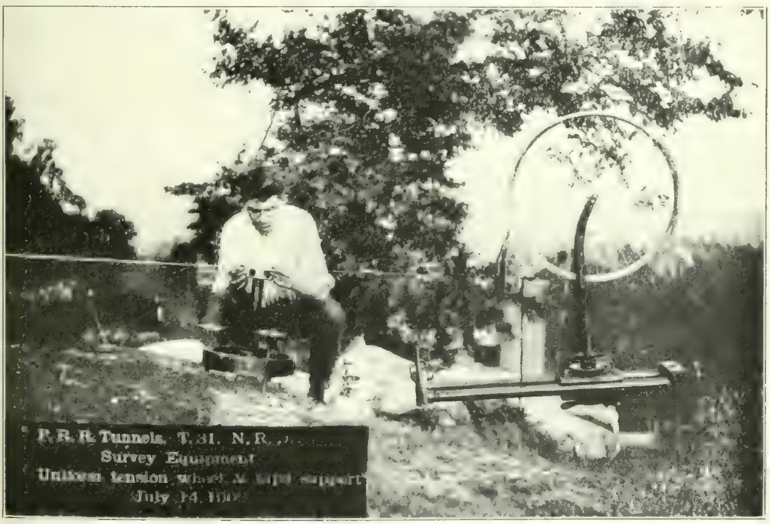


FIG. 2.—UNIFORM TENSION WHEEL AND MOVABLE STATION POINT, OR "SPIDER," USED IN BASE LINE MEASUREMENTS. PENNSYLVANIA RAILROAD TUNNELS.

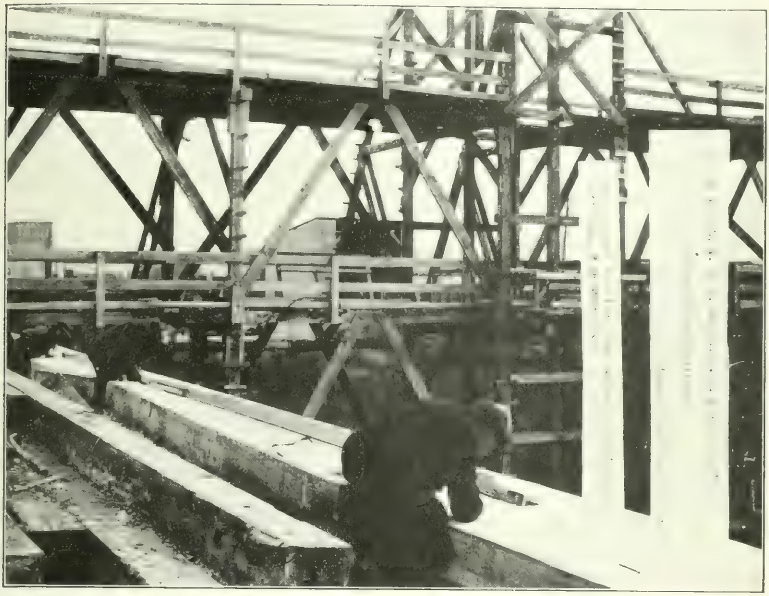


FIG. 1.—BEAM COMPASS, 37 FEET LONG, SET ON BASE, NORTH WALL, WEEHAWKEN SHAFT. PENNSYLVANIA RAILROAD TUNNELS.

FIG. 2.—TRANSIT ON CENTER LINE, SOUTH TUNNEL, WEST WALL, WEEHAWKEN SHAFT, SET IN POSITION BY A SECOND TRANSIT, AND LINING IN PLUMB WIRE SUPPORTED BY GANTRY.

of the tape was determined by a level. All work was done at night so as to avoid interference by traffic and obtain more uniform temperature conditions. By this method the use of the plumb-bob was eliminated, the measurements being taken by direct contact with the top of the movable station point, and being carried from station point to station point. Mr. Cresson.

The monuments at the ends and along the base lines were tied in by sighting a transit (set up at right angles to the base line at the monument) on the point of the monument and reading on the tape. No effort was made to keep the tape level, elevations being taken at both ends to determine the slope. The results obtained by this method appeared to be very satisfactory. Different tapes were used on different nights, and a comparison was made between the results obtained on one base line on one side of the river and the other on the other side of the river, to aid in determining the coefficient of the tape.

In the river quadrilateral, the lengths of the base lines were, respectively, 2 263 ft. + and 2 242 ft. +, and the distance between the base lines was 6 688 ft. +. The smallest of the angles was 18° 41′ +, which was somewhat smaller than desired. The angles were turned with a 7-in., 10″ transit, which was set up, not by plumb-bobs, but by sighting other instruments on the monument and on the transits themselves. This was particularly necessary at the triangulation tower in Weehawken, which was 60 ft. high, as there was constant movement at the top of the tower.

The angles were read by a number of observers, and the whole system was carefully balanced, not only with respect to the angles, but also including the measured base line.

The levels were transferred across the river by prolonging a level base alternately from each side of the river, and the averaged results corrected themselves for the earth's curvature and for refraction.

The method of laying out parallel lines was to use a beam compass 37 ft. long—the distance between tunnel centers—and, from one tunnel line, to set off the parallel line. Excellent results were secured in this way, as the wooden beam was not affected by temperature or by tension.

There were many other details of these surveys and of the calculations which the speaker believes would be of interest if presented.

Robert Ridgway, M. Am. Soc. C. E.—Mr. Noble has treated his subject in such a comprehensive way as to leave little to be said in discussion. The speaker has some knowledge of the work described, having been connected with it in its earlier stages, and regards it as the most difficult piece of tunnel surveying with which he is familiar. Mr. Ridgway.

The shafts on the opposite sides of the river were not visible from each other, the line of sight between them being obstructed by trees

Mr. Ridgway. and structures, and the use of auxiliary alignment points was required. Two horizontal curves, one about 2 000 ft. in length, made it necessary to establish seven or more angle points in the tunnel. On the Brooklyn side the tunnel was in sand and silt, and the tubes shifted slightly for some time after the line points were established in them, making repeated checkings necessary in order to avoid serious error. In addition, the driving of the tunnel through the sand caused more or less surface disturbance, which affected the position of the alignment points on top, making it necessary to refer them carefully to offsets some distance back in the cross streets.

There was also the difficulty of passing the lines and levels through the air locks. To accomplish the successful results described by the author, in spite of these trying conditions, called for the patient application of sound common-sense methods. One does not realize from a reading of Mr. Noble's concise paper how much patient work was required to overcome the difficulties.

It is gratifying to know that the satisfactory results were obtained without the use of special instruments or appliances, only the ordinary surveying equipment of a tunnel construction party having been used.

Mr. Purdy. S. M. PURDY, M. AM. SOC. C. E.—This paper is of great interest to engineers who are engaged in making surveys for important works, and will prove helpful to many. The literature on this subject is so meager, that many devices and methods which have been found highly successful by engineers in certain localities are unknown to their brethren, who have not been so fortunate as to observe their use. As an exposition of tunnel survey methods, triangulations, and base line work under most trying conditions, this timely paper will no doubt arouse considerable interest and lead to valuable discussion.

In base line work, or in measuring tangents, where accuracy is required, the writer has found that the observation of a few simple principles has uniformly led, not only to excellent results, but to a great saving in time and labor.

Stakes or points are set on line with transit and tape in the usual manner, the stakes being driven at intervals somewhat less than the length of the tape to be used in the final measurement. This is in recognition of the fact that an unknown distance can be measured with a greater degree of accuracy than a known distance can be laid off. Also, if unknown distances are used, they can be checked with greater certainty, the personal element entering to a less degree, and the tendency to repeat errors being almost entirely eliminated. The writer has usually placed the stakes about 99½ ft. apart for a 100-ft. tape, and a corresponding distance for other lengths of tape. Tacks (usually small brass brads) are driven arbitrarily in the stakes for definitive points. The differences of elevation between adjacent stakes

are next determined by a line of levels and are used in maintaining the level of the tape. Where possible it is desirable to hold the zero end of the tape fixed on one point, thus obviating the necessity of using two plumb-bobs. Thermometer readings are taken and recorded with each measurement. Mr. Purdy.

During the construction of the Torresdale Conduit, in Philadelphia, the writer was called on to do work which was similar to that described by Mr. Noble. This conduit is a pressure tunnel, 10 ft. 6 in. in diameter, after lining, and is about 14 000 ft. long. It was driven through the rock at an elevation averaging 100 ft. below the surface of the ground, and the headings were reached through nine temporary and two permanent shafts. In transferring the alignment from the surface to the tunnel, the following method was used: A wooden stringer was placed across the top of the shaft, parallel to the center line and about 1 in. therefrom. To this stringer were fastened hangers, similar to those described by Mr. Noble, to which were suspended soft iron wires of No. 18 gauge, the latter sustaining weights (usually a piece of scrap iron) of about 30 lb. The distance apart of these wires, forming the length of the base line, was determined by the conditions of the shaft, but in all cases was as great as possible, varying from 3.2 ft. in Shaft No. 7, to 10.4 ft. in Shaft No. 4. It was not generally found necessary to place the weights in water, as it was thought that a small oscillation of the plumb wires was preferable to absolute steadiness.

A transitman, whose instrument was set up a short distance from the shaft, kept the tops of the plumb wires in alignment by constantly testing them, checking his own position at frequent intervals.

Two transits were used in the tunnel. They were set up at either side of the shaft, about 15 ft. from the nearest wire. These transits were equipped with a special device by which a lateral motion could be attained with a slow-motion screw. Each transitman proceeded to align his instrument with the two wires, observing first one and then the other. When a transitman announced that he was on line, he was required to set a stake about 100 ft. away from his instrument, using his foresight. Subsequently, the second transitman set a similar stake. Observer No. 1 then plunged his telescope and tested the point set by Observer No. 2, and Observer No. 2 sighted on the point set by Observer No. 1. In this manner a base line some 200 ft. long was established in the tunnel, which was immediately referenced to permanent points. A week or two later this entire proceeding was repeated, and if the two lines failed to agree, a third test was made. This was found to be a rapid, convenient, and accurate method for transferring lines, and the work was easily performed during the noon hour, when tunnel excavating was not in progress, thus causing practically no inconvenience or delay to the contractor.

Mr. Purdy.

Lines were carried into the headings as the work progressed. Points for line and grade consisted of horse-shoe nails through the heads of which were drilled holes $\frac{3}{16}$ in. in diameter. These nails were driven into wooden plugs which in turn were driven into drill holes in the roof of the tunnel. Plumb-lines were suspended from the nails whenever it was desirable to use a point. For excavating purposes, a piece of blasting wire was fastened to the nail and to this was tied a small stone. When not in use the wire was coiled up out of the way.

During 1898 a large topographical survey was made by the United States Deep Waterways Commission. Incidental to this survey, a triangulation was made of Oneida Lake, a body of water about 20 miles long, and from 2 to 6 miles wide. For this work an ordinary transit with verniers reading to 20″ was used. A requirement of the Commission was that quadrilaterals should close within 10″. At first, there was some difficulty in meeting this requirement, and the experiment was made of reading the angles at night, using lamps as stations. This proved highly successful, and night observations were continued until the completion of the work.

The whole triangulation was made during the winter while the lake was frozen. Both the starting and closing base lines were measured from shore points across intervening ice. Standard tapes, 100 ft. long, were used, lying flat on the ice, the proper tension being applied by a spring balance.

The method of repetitions was used in reading the angles. The party consisted of an observer, two vernier readers, and a recorder. A complete set of readings for any angle consisted of six sets of six repetitions each. The vernier was first set at zero and pointings were taken from left to right, both verniers being read each time. After reading the angle, then twice the angle, and so on for six pointings, the observations were taken from right to left until the plates were brought back to zero. Failure to check as close as 20″ caused the rejection of the entire set. For the next set, the vernier was set at 60°, and readings were taken in a similar manner. For the third set the verniers were set at 180°, and so on. By changing the set of the vernier each time, the whole limb of the transit was brought into use, and any errors of eccentricity which may have existed were eliminated.

The writer is of the opinion that observations taken at night would be of material assistance in triangulations in and about a large city. Certainly the atmospheric conditions at night are more equable, and as there is less traffic there is less vibration and also better opportunities for rapid work. Again, a flame affords several advantages as a point on which to sight, freedom from phase being perhaps the most important.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROBLEM OF THE LOWER WEST SIDE MANHATTAN WATER-FRONT OF THE PORT OF NEW YORK.

Discussion.*

By Messrs. S. W. Hoag, Jr., H. McL. Harding, James Forgie, Edlow W. Harrison, Charles H. Higgins, and M. Lewinson.

S. W. Hoag, Jr., M. Am. Soc. C. E.—Mr. Cresson has struck the key-note of the present situation affecting the future of the Port of New York when he refers to conditions and the formulation of a policy which demand the re-organization of the port. The speaker is disposed to lay some stress on this expression, because it emphasizes the fact that the further progressive and up-to-date development of the water-front has brought the City face to face with the necessity for wise discrimination between the past and future ways and means. In view of the agitation which this subject is receiving, and the efforts being made to arouse public sentiment in regard to the situation, it is necessary, in arriving at an intelligent conclusion, to understand and to appreciate at its full value all that has been done by the City of New York leading up to the present time. Mr. Hoag

Particular attention is called to this feature because of the fortuitous circumstances which have led to the present situation. In 1870, when the systematic development of the City's water-front began, no one but an infallible prophet could have foreseen, either the abnormal growth of the Metropolitan district, or the momentous improvements, in the matter of inland water communication with the Great Lakes, as exemplified by the New York State Barge Canal, and the great inter-ocean communication, as exemplified by the Panama Canal, each of which, the one inter-state and the other international, has a

*This discussion (of the paper by B. F. Cresson, Jr., M. Am. Soc. C. E., published in *Proceedings* for January, 1912, and presented at the meeting of February 21st, 1912), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Hoag. direct bearing on any consideration of adequate facilities for the Port of New York.

When, by an Act of the Legislature, the Department of Docks was organized, in 1870, nearly half a century ago, it should be noted that the authorities, at the inception of their work, advertised for all persons who were sufficiently interested in the improvement of the water-front, or who had any ideas on this subject, to attend hearings, discuss schemes for improvement, and offer suggestions. Numerous propositions were submitted, and are now on file in the Department of Docks and Ferries. Surely that was the opportunity for any prophetic announcements or estimates.

The resulting "New Plan," submitted to the Board of Docks by General McClellan, then Engineer-in-Chief, was so far superior to anything proposed by those who responded to this invitation, as to place most of the suggestions in the category of curios. At any rate, the conditions existing at that time, and for many years after, in the Port of New York, and it might be said in the marine world, affecting the City of New York, which was Manhattan Island with the addition four years later of that portion of the Bronx west of the Bronx River, did not justify anything more elaborate than, or particularly different from, what was then designed. The New Plan had the approval of all commercial bodies, and for years has been the primal force in making the Port what it is to-day. Relative to this matter, it should be borne in mind that the water-front improvements made by the City have been self-sustaining, the annual net revenue received from the operation of all the properties under the jurisdiction of the Department of Docks and Ferries, as of December 31st, 1910, being $3 000 000.

The conditions that have arisen in recent years were not foreseen, nor could they have been foreseen; for, while the importance and supremacy of the Port were inevitable from the start, the magnitude of its growth, within the period between 1870 and the present day, was not even dreamed of. Take for illustration the increase in length of trans-atlantic steamers as indicated by the vessels of the Cunard Line. In 1840 its longest vessel was between 200 and 225 ft. In 1870 the *Russia* was 315 ft. long, an increase of 175 ft. in 30 years. It was reasonable to expect a corresponding increase, at least, during the next 30 years, but in 1900 the *Campania* and *Lucania* were 625 ft. long, or only 75 ft. more than what might be termed a normal increase. In the next nine years, the longest vessel entering this Port, was the *Lusitania*, of the same line, with 790 ft. The jump in 39 years was from 375 to 790 ft., or 415 ft., the increase being greater than the length of the longest steamer in 1870. Two years later the *Olympic*, of the White Star Line, the largest steamship in the world, with a length of 862 ft., entered the harbor, and has been docked successfully at regular intervals at the Chelsea Section ever since. This is only

one instance, cited to show the rapidly increasing magnitude of port conditions covering the latter part of the period during which the Department of Docks and Ferries has managed the City's water-front. Mr. Hoag.

The combination of these almost anomalous strides in magnitude, involving both marine and railroad requirements, is what has created the condition which to-day demands thoughtful consideration and immediate relief. No port in the world has had the experience of New York in these questions, and when the development of the water-front was originally planned, there was no port from which suggestions could have been obtained leading to the adoption of plans which would have avoided the present difficulties. Most of the foreign or European ports are artificial, and more or less confined to comparatively small areas, and in no instance is there the God-given opportunity for expansion that exists here. The unique experience of New York during the past decade, and the present conditions, must furnish the guide for other ports in the future, and some of these have already begun to profit by the lesson, and have inaugurated extensive improvements in their facilities.

When the symptoms of this unusual activity first became manifest, about 12 years ago, there was an available stretch on the North River water-front of Manhattan which was conveniently located and well adapted for the necessary expansion. This frontage was utilized by the development and construction of the Chelsea Section Steamship Terminal, which has been built, occupied, and operated, within the last ten years, by the largest steamships that enter any port in the world. Any further expansion or utilization of the North River Manhattan water-front for such purposes must depend on the reorganization of the lower Manhattan water-front by the elimination of the "marine car yards," of the various railroads, which occupy about 47% of this section.

There are three terms which the experience of New York must inevitably conserve in any modern comprehensive port development—articulation, co-ordination, and organization. These terms speak for themselves; for, without articulation, a heterogeneous mass of units, having no connection with each other, is bound to result. Even with articulation, but without co-ordination, confusion is apt to follow; and with articulation and co-ordination, but without organization, there are bound to be periods of spasmodic confusion and lack of cohesion. It is the recognition and observation of these three factors that make this subject so important, and its discussion so timely.

The loyal spirit of the New Yorker for his native city, and his inextinguishable pride in the Metropolis, are bound to make themselves manifest in no uncertain terms whenever the occasion arises that demands the consideration of anything that appears to be necessary for the maintenance of its supremacy.

Mr. Hoag. The City of New York moves on lines which, to a stranger, might appear to be inconsiderately slow in many things. The spirit of the metropolis in such matters is extremely conservative, and is opposed to experimenting with the people's money. They had the electric light in the streets of Duluth before New York City ever adopted it; Chicago had its Masonic Temple before the sky-scraper appeared in New York; the trolley car was in operation all over the United States (even in Brooklyn, prior to consolidation) before it appeared in Manhattan, but when it did come, it was the underground trolley. In other words, the motive spirit of New York City is to prove the successful accomplishment of many so-called improvements elsewhere, or to "let the other fellow try it out," before adopting it.

All of this is pertinent to the present attitude of the Department of Docks in its desire and attempt to obtain the very best solution of the North River water-front problem with its attending environment, for it should be recollected that this proposed solution is the result of a study of conditions in all the big ports of Europe and the United States; but, in so far as Manhattan is concerned, there is probably no place in the world that is confronted with such adverse geographical and local conditions in meeting the requirements for all-rail connection with the rest of the United States without an extensive outlay; and the logical solution to-day would doubtless have been considered extravagant and unnecessary even a quarter of a century ago.

Mr. Harding. H. McL. Harding, Esq.*—Mr. Cresson has stated so fully the conditions in reference to the terminal arrangements for the transference of miscellaneous freight along the North River water-front, that little can be added.

From a conservative engineering standpoint, it seems as though the plan outlined should receive the commendation and support of all civil engineers, and especially of those who are familiar with the energetic and untiring exposition of Calvin Tomkins, Assoc. Am. Soc. C. E., Commissioner of Docks and Ferries, for the furtherance of these greatly needed improvements so essential to the foreign and domestic commerce of the City of New York.

This complete plan may be considered as the best suggested after twenty-four years of commissions, reports, and discussions. The necessity for improvement has long been recognized.

There are two general facts which cannot be gainsaid, and concerning which there should not be any discussion. One is that there are a number of steam-ship companies (twenty, the speaker believes), clamoring for berthing facilities to land and receive cargoes of industrial freight. The other is that better facilities for freight receipts and deliveries are desired, not only by the shippers and consignees, but by the railroad companies.

* Consulting Engineer, Department of Docks, New York City.

Clearing away the mass of objections, some sincere, some not disinterested, and some due to a proneness to argument, there seems to be a consensus of opinion as to the methods in general, and any discussion is rather on the details of application and operation. Mr. Harding.

There are several questions asked: One is, "Is it possible to find room anywhere for these steamship companies along this water-front?"

By considering the railway problem first, the answer to the above may be more clearly understood. Chicago has 250 freight stations, Philadelphia and other large cities also have many, even when there is practically one railway company in control. These stations are located in different sections of a city so as to obviate long drayage hauls by the merchants and also to prevent the impending and increasing package-freight traffic congestion.

That a number of such freight receiving and delivery points are necessary, has long been conceded; but there will not be economical service at these sub-stations unless there are rail connections with some central freight or transfer station. For Philadelphia, one central transfer station is at Mantua where the cars from the sub-stations are assembled and the freight is redistributed so as to obtain greater carloads for designated points. At this same transfer station there is a further interchange and reloading of both the in-bound and out-bound local car load freight.

In New York, below 23d Street, this sub-station collecting service, including the assorting, is carried on at the bulkhead sheds, these being the station, and cars on floats in the slips the freight yard. There are a few sub-stations away from the water-front, as at St. John's Park which is connected by surface railway tracks. These tracks should be removed from the streets, in the interest of both the city and railway. If the railways did not occupy these bulkheads, piers, and slips, they would be available for the steamships. There are some twenty-eight piers occupied by six railway corporations, and in some cases four of these piers, within a few blocks of each other, are under one control.

Sub-stations are essential to the business of the merchants of New York, but are there not other places where they can be located more advantageously than at the piers and slips, thus avoiding the present congestion, and yet releasing the slips and piers to water transportation? This congestion is so acute that in a bulkhead frontage of 216 ft., as much as 400 tons of package freight is handled during 3 hours. A freight station should have at least 800 ft. for this service. As shown by Mr. Cresson, there are such places, and, due to the long, narrow configuration of the Island of Manhattan, stations can be distributed so that long hauls are not necessary. In addition, there are modern mechanical methods of freight transference which will

Mr. Harding greatly increase the capacity for any given space to three and four times that where the floor area and one level are occupied by trucks.

By good fortune, this portion of Manhattan has not yet been improved, but is largely occupied by rookeries and tenements. This space is along the east side of West Street below 23d Street. As it would not be available unless there should be rail connection, and, as surface tracks cannot be permitted, and a subway has been decided as not practical along the lower portion of the Island, an elevated railway is the only alternative. This is the whole story condensed, and is the final conclusion after many years of deliberation.

There are the following pertinent questions:

First.—Will there be the necessary space for the cars, the drays, and for receiving and delivering the freight?

Yes, but not for car placement for assorting according to cities. This should be done elsewhere, at a transfer station, either above 23d Street, where the land east of the marginal way is already owned and occupied by the railroads, or in New Jersey, as shown on Mr. Cresson's map, Plate V. Instead of the twenty-eight sub-stations now within this 2½ miles from 23d Street to the Battery, a less number should be sufficient and yet permit the stations of the different railway controlling corporations to be equally accessible to their present or prospective customers. These stations would occupy the first and second stories of high buildings constructed on the east side of West Street. The third floor could be used for stored or held-over freight.

The tonnage to be transferred daily, including the in-bound and out-bound freight, would not exceed, as a maximum, 300 tons per hour per station for some time to come. At one station, now congested, 700 tons are handled daily, and, at another, 1 000 tons; but, within about 3 hours in the afternoon, more than half of the above tonnage is handled. At present, the freight must be removed as quickly as received, to keep the bulkhead frontage clear. This would not be so necessary if there should be more room, though it would be advisable in order to secure quick car loading. The space required for transferring 300 tons per hour will be given and described later, with other requirements.

Second.—Can dray congestion and delay be avoided?

Yes, absolutely; provided the whole first or street level floor is reserved for the drays and their platforms, and the second floor for cars, car platforms, and the longitudinal openings between the floors, the station being equipped with overhead transferage runways, electric transfers, and transfer trailer hoists.

All platforms and other space within the range of the machinery should be served directly by this machinery; there should be no rehandling by manual labor, and there should be continuous rapidity, that is, no lost-labor time waiting for the return of the machinery. One machine should follow another so closely that the operation should

be practically continuous. The out-going freight should be placed on flatboards when received from drays, each flatboard holding one consignment for convenience in weighing, and, though the consignments are separated, yet at least three consignments should be hoisted and conveyed simultaneously, each being weighed when passing over a section of the track connected with scales. Mr. Harding.

Each string of cars should be loaded to their full capacity, and, as soon as ten or more railway cars are fully loaded, they should be despatched to the transfer station. It should be possible to load any car from any platform, the load passing by gravity rollers within the car, after it has been lowered by the trailer hoist. Similarly, the in-bound freight should be taken from the cars, but held awaiting the arrival of the drays of the consignees. There is a space reserved on this second story for storing some 2 000 tons or more of in-bound freight.

Within a space of 200 by 200 ft. on the ground floor there could be transferred more than 800 tons per hour from drays. This is an average load of 1 ton per dray, due allowance being made for the dray area and platforms. As 300 tons would be the maximum, the foregoing is given to show the approximate capacity of a frontage of one block. Two stations, therefore, could be easily accommodated within this space, avoiding dray delay and congestion either within or without the station.

On the second floor, 600 tons per hour, and even more, could be loaded into cars brought from the elevated railway on the same level and despatched. There would be space here for the cars, platforms, and openings. In an engineering report, the size of the platforms, the number of drays, the average loads, the space occupied per dray, the time to load or unload, the average tonnage per car, the time required to load and unload the cars, the space for car platforms and openings, and other data, will demonstrate the correctness of the foregoing statements, but the operation can only succeed by the use of mechanical appliances. This use of machinery has been considered in calculating the area capacities. There would also be ample capacity on the four tracks of the elevated railway for all the car movements, continuing these to such a proportion of the 24 hours as the volume of freight would warrant.

Third.—Will the railways now using the bulkheads and slips accede to the change?

This question can also be answered in the affirmative, provided the City will afford such facilities that the proposed locations will remove the present congestion, offer greater and permanent advantages as to economy and rapidity than they have at present, and furnish separate or combined terminals, according to the option of the individual railway companies. The railways, however, want no particular railways to have superior advantages.

Mr. Harding. It now costs about 40 cents to handle 1 ton of local car load package freight from the bulkhead frontage into the cars, including the usual operations of inspecting, weighing, routing, and checking, and 40 cents more to transport the freight over the river, and more than 10 cents additional on the other side for the car movements; probably a total of 95 cents per ton would be a fair average for comparing costs of identical operations.

If the City will provide the elevated railroad, the tunnels as shown on Plate V, and the collecting and delivery terminals mechanically equipped, for 4% interest on the cost, on the same basis as the terminals of the water transportation companies (these terminals being self-supporting), and with a fair charge for switching the cars through the tunnel, the railways should be able to give better service and at less cost than at present. This statement as to less cost may be disputed, but if mechanical appliances are properly installed, with a full knowledge of the operating conditions, and according to engineering experience as to what the machinery can do, the greater rapidity and economy can be secured. The advantage of being able to assort into the cars on the floats is largely, if not wholly, nullified by the extra expense of the long trucking, averaging some 700 ft., and the cost of transporting across the river so many cars only partly loaded, together with the expense of the transfer bridge and the subsequent car switching. The following figures may serve as a basis for comparison:

Present Partial Costs, per Ton.

Pier rentals	8 cents.
Expense of handling	40 "
Transporting expenses (actual)	40 "
Switching	7 "
Total	95 cents.

Costs Under Improved Conditions, per Ton.

Station rentals with better and permanent locations (based on greater area and tonnage, out-bound and in-bound, and trucking space), and using only two stories	5 cents.
Expense of transferring from dray to car and *vice versa*	12 "
Transporting to New Jersey and switching	15 "
Mechanical assorting at transfer station in New Jersey	12 "
Total	44 cents,

a total saving of 51 cents per ton.

If these figures are accepted as only approximately correct, where is the claimed advantage of assorting the light loads into many cars on floats, especially as these cars often go to transfer stations? Mr. Harding.

There are many other conditions which must be carefully weighed, but these brief statements may open the way for a further discussion from which exact figures may be obtained to substantiate the foregoing conclusions.

The railway companies will soon need more room to handle their increasing package freight, and the dray congestion of the merchants has reached the limit of sufferance. Every conceivable plan has been advanced; but, the one cited by Mr. Cresson, of an entire rail haul, from a number of independent sub-stations, appears to be to the advantage of the whole city, shippers and consignees of freight as well as transportation companies.

JAMES FORGIE, M. AM. SOC. C. E.—Mr. Cresson's paper has been endorsed so thoroughly that it seems to be unnecessary to add to that endorsement, but it may be further emphasized. This problem is to restore the water-front to its proper use, to do away with floating railroad yards, and put them in their proper place, and to remove the railroad tracks now occupying the surface of exceedingly busy streets. Mr. Forgie.

Mr. Thomson has referred to the enlargement of Manhattan Island by connecting Governor's Island to it with sea-walls and filling in. Is it not rather a pity to introduce such a far-in-the-future solution? It would seem that the introduction of such a subject is departing from the issue. The immediate issue is the relief of these difficulties, and the solution is applicable now, and would be applicable to any extension or prolongation of Manhattan. Mr. Thomson states that the extension of Manhattan "could be" done in 5 years. Mr. Cresson's plan can be carried out, including the lines and yard in New Jersey, the tunnels under the Hudson River, and the elevated line in New York City, in 2 years.

Is it not to be regretted that Mr. Cresson introduces a compromise into his paper? Doubtless, however, he has reasons for this. Why should transfer bridges be constructed in the neighborhood of 40th Street, when the tunnel scheme can be completed in so short a time? There are two other schemes in connection with this problem. One of these includes small marginal tunnels, but this involves relief by breaking bulk, while the author's solution brings in the traffic directly on the original cars down the water-front, independent of the street traffic, so that they may be flexibly diverted at the high elevation either to the piers, the warehouses, or the yards on the east side of West Street, as the case may be. The other scheme—and a bad one—is a concentration of transfer bridges at certain places on the front, retaining carriage by float across the busiest harbor in the world, and

Mr. Forgie taking the trains across to the east side of West Street in what seems to be a complicated and impracticable way.

Mr. Cresson deals with an attempt to dissolve serious interferences in the economic handling of freight to and from Manhattan Island, the misuse of the harbor front, and the chaos prevailing in West Street, owing to railroad trains at grade and other traffic which can be handled better elsewhere. In the speaker's opinion, Mr. Tomkins and Mr. Cresson are to be congratulated on having formulated a simple and direct means of accomplishing this at a comparatively small expense, which, it seems, can be more than carried by the saving in the handling of freight alone. Manhattan Island is becoming more and more of a financial center and less of a manufacturing center, and such freight handling as is necessary should be transferred from the water-front as much as possible to areas more capable of development, and fed directly by rail and not by car float. The expense of the car-float arrangement has been pointed out time and again, and, while it cannot be abolished in a day, the policy should be to eliminate this traffic gradually, within economical limits, and obtain direct entrance to the water-front by rail; in this instance, there is a possibility of doing so with benefit to all concerned.

New York has enormous natural advantages as a port, and by a tour around its great frontage, any intelligent observer can readily see a lack of commensurate development and that it is also beyond the stage of having freight yards in its public streets and on its important water-fronts.

From one's office windows can be seen the conditions pertaining to the greatest trans-oceanic port in the world, which are more suited to the surroundings of Newtown Creek. Can one doubt that while Manhattan is the great port it is, it would have been still greater as a port for foreign and coasting vessels had the harbor front been available for such a purpose? At the present time the dockage in Hoboken proves this. As it is, the Manhattan front is to a great extent a floating railroad yard, and West Street is in many respects more a warehouse and storage-room for freight and vehicles than a vehicle of dispersion.

Recently the speaker listened to Mr. Bush, of the Bush Terminal Company, who is doubtless an authority on water-front development, and the gist of his statement was to the effect that shipping should not be waiting for port facilities, but that port facilities should be waiting for the shipping, and that the more the shipping capacity of the water-front around New York was increased, the more the hinterland improved and the more the business of the port developed. This paper is a very complete suggestion or plan of what is considered the best means of utilizing this frontage to its capacity by the removal from it of that business which can be handled better and more economically

elsewhere, giving greater facilities for the disposal and acquisition of railroad freight, and elevating the railroad tracks which are now a nuisance in the streets. Mr. Forgie.

The freight business in New York is so great, that to sort freight cars on floats while trucks wait outside in the front street is, in this location, surely out of date when it is known that this particular traffic can be accommodated by some other means to the greater advantage of all railroads, and with great economy and saving in time. The plan to gather the freight cars of the railroads in a yard in New Jersey, sort the trains, and bring them into New York without breaking bulk, by means of a belt line in New Jersey, under the North River, and down the water-front on an elevated line, is surely far the best solution of the difficulty.

As far as the construction of tunnels under Bergen Hill and the Hudson River is concerned, that is a simple matter; as far as the elevated railroad is concerned, that is still simpler. There can be no esthetic reasons for prohibiting such a structure on the west water-front.

As a rule the speaker advocates the depression of tracks in cities; but on the harbor front there is no reason for doing this with these freight tracks. On an elevated structure they would be at a suitable level for rapid disposal, either into warehouses or on the piers, whence freight can be handled much more readily than on the ground level. This scheme would put every railroad on an equal footing; it would bring all freight in from the West, or from anywhere else on the west bank of the Hudson—or for that matter, from the North without breaking bulk, and would be much more flexible than a tunnel system.

Suppose the tracks were depressed in West Street, or on the water-front marginal street all around the island, one can readily understand that extension into warehouses, freight yards, piers, sidings, etc., from such a subway would in all instances be very expensive, and would waste much useful ground space in approaches and shunting areas; on the other hand, from an elevated line, all such connections would be extremely flexible and comparatively inexpensive. What reason can be given, commercially or esthetically, against an elevated structure with elevated connections on the water-front streets, where enormous quantities of freight have to be handled and where people do not reside?

The only objection to this scheme is the fact that it will add to the abnormally advantageous position which New York now occupies—how much better will the citizens of New York be 30 years hence, when its population will be double what it now is as a result of its accommodating its passenger and freight-handling business in a scientific manner? If we must increase commercially, we must do as

Mr. Forgie. any up-to-date factory does—scrap the old for better means of economical results.

While observing the neglect and lack of appreciation of the extraordinary natural advantages of New York as a port, the speaker cannot but contrast it with the comparatively small ports on the east coast of Scotland, where harbors have been dug out of the solid rock at a vastly greater expenditure per capita than New York would have to meet, and for incomparably less return.

Mr. Harrison. EDLOW W. HARRISON, M. AM. SOC. C. E. (by letter).—Mr. Cresson's paper should be welcomed as a timely contribution on a subject which, in the minds of many thinking men, is becoming of supreme importance.

All signs indicate that this century is to see an enormous development of world trade, and that the United States, with its unequalled resources and millions of intelligent workers, will lead in this movement, and that the measure of its lead will depend, very largely, on the value of the facilities given by the Port of New York.

The subject and the problem are national, not local, and must be treated on the broad lines of national continental policy.

The writer does not wish to tread on any one's toes, or to belittle the earnest efforts of many honored citizens and distinguished engineers who, from time to time, have interested themselves in the development of the Port of New York, but he cannot help saying that the interest, in the past, has been largely of a narrow, provincial, and selfish character.

By its natural position and the course of growth of the continent behind it, the Port of New York has become the principal gateway of the nation. All roads lead to it, both from the interior, and across the ocean. There are no indications that its supremacy will decline for many years to come, but, on the methods of its development, and the economy of its operation, as a world port and as a factor in securing the leadership in the trade of the world to the people of this country, the relative welfare of many millions depends.

There has been too much endeavor to concentrate and congest commerce on the Island of Manhattan. The feeling has been: "Our Bay," "Our River," "Our Commerce," "We must hold it, not as a trust for the nation as guardian of its gate, but because we need, and must have, the incidental return, the tariff, or the 'rake off,' from having its commerce touch Manhattan." The attitude has been that of the commercial ports in the sixteenth century; to force the stream by laws and regulations.

To paraphrase the old quotation, we should do as the London of to-day does: "Let us negotiate the bills of exchange and furnish the cash for the commerce of the world. We care not what stevedores

handle the freight; what railroad or vessel carries it; or through what port it passes, provided the charges are the lowest obtainable." Mr. Harrison.

London may have carried this principle too far, and allowed her port facilities to fall behind the times, but she is now remedying this neglect.

The writer is glad to say that the present Commissioner of Docks and Ferries has taken a broad view of the necessities for the future of the Port in his capacity as a member of the Joint Commission, appointed by the Governors of New York and New Jersey, to examine into and report on the development of harbor facilities, and it is with the heartiest appreciation of Mr. Tomkins' sincerity that he ventures to criticize certain of his plans, mainly because they seem to him to have been devised without a proper consideration for the actual conditions surrounding the problem, and to be a continuation of the narrow medieval policy.

The Port of New York, taken as a whole, may be said to cover all the enclosed waters inside of Sandy Hook and Throgg Neck, including the Amboys, Arthur Kill, Newark Bay, and the lower Passaic and Hackensack Rivers; Kill Von Kull, the Upper Bay, the lower Hudson, and the East River to the Sound. Within these boundaries, and as a whole, this Port is equal or superior to any commercial harbor in the world, for ease of entrance for vessels even of the deepest draft, moderate tide, comparative freedom from ice, good holding ground for anchors, extensive shore line, advantages for shore front improvements, docks, wharves, and piers, at comparatively moderate cost, easy and cheap dredging, and convenience of communication between all its surrounding shores. It is within 24 hours by passenger time, or 48 hours by fast freight, of a population exceeding that of Great Britain or France, and is the market for every possible production known to civilized man.

All parts of this harbor, however, are not equally valuable for the commerce of to-day. In the years before 1865, the Island of Manhattan, constituting the old City, was the most favorable site for commercial operations in the Port and in the country, and it had then attained, and had held for years, the commercial supremacy it still holds. To-day the Borough of Manhattan is probably the most unfavorable and least economical district of the whole Port for handling and transferring freight, and can only maintain its position by expensive and artificial forcing of the natural course of commodities. It is living on old traditions under radical changes of conditions.

A little study of the course and growth of commerce in the past half century will show that this is no careless statement, but a very serious fact. Before 1865, New York's commerce was by water carriage. Her coal came by canal barges *via* the Delaware and Raritan to Amboy, the Morris Canal over the mountains from Easton, the Delaware and

Mr. Harrison. Hudson Canal and Hudson River from Rondout, or by sailing vessels from Philadelphia, with a small amount brought over the single track of the Central Railroad of New Jersey to Elizabethport, and then to New York. Wood and charcoal came by sail up the coast from the Chesapeake. Cereals, flour, quantities of food stuffs, and lumber, came through the Erie, Champlain, and Oswego Canals. Meat was largely of State or Ohio raising, and large droves of cattle, hogs, and sheep were driven, on the hoof, from the Mohawk and Genesee Valley to the Hudson, and then carried by steamboat to the city. New York was a city of wood, brick, and Belleville brown stone, or Vermont marble, with cast iron from the Highlands, Troy, or Paterson furnaces—all by water carriage. Fruit, vegetables, and dairy products came by canal or river boats from up river, New Jersey farms, Long Island, or the Sound. Fish and oysters, of course, came by boats. Philadelphia and Baltimore trade was by boat through the canals, as was that of all tide-water New England. Textiles, when not imported from abroad, came by Sound boat from New England mills. Cotton, corn, sugar, and all Southern products were, of course, by coastwise shipping.

As now, one railroad entered the city from the West, but its freight tonnage and capacity for business, compared with to-day, were almost negligible quantities.

Across the Hudson, New York's rail connection for freight to the West was by the united railroads of New Jersey, with yard capacity for about one hundred cars at Jersey City, and the same at South Amboy. The Erie had only just completed its tunnel, and was still handling its freight by boat, *via* Piermont. The Reading, Lehigh, Lackawanna, and West Shore had not reached New York Harbor. An ocean-going vessel, from 300 to 350 ft. in length and of 3 000 tons burden, was a big ship.

New York Island, with no part of its surface more than a mile from navigable water, with a population of about 900 000, with plenty of labor, which was being added to weekly by hundreds of European workers of the best class, with good banking facilities, and ample capital and credit, with vacant land at reasonable cost, and with good sanitary conditions, was unequalled by any seaport town of the country as a transhipping point for commodities, combined with advantages as a manufacturing center, and a mart for trade, wholesale and retail.

With the development of the country, all this has changed. The commodities seeking the Port of New York have increased in volume many fold, but the increase has been in rail tonnage. Steel rails, larger train loadings, and more powerful engines, have driven the water-carried goods to the rail. Two freight cars out of a train of forty or fifty will convey a good loading for a canal boat at a fraction of the cost and time of carriage; but, with the exception of one road—the New York Central—all the great carriers from the West and South

only reach the west side of the harbor with their rails. The great city, with the exception of the Borough of Richmond, is dependent on a forced arbitrary rule to hold her position. Mr. Harrison.

Under present regulations, all points around the Harbor enjoy an equal tide-water rate and free lighterage within liberal limits, notwithstanding the fact that it costs 60 cents upward per ton more to deliver or receive freight on Manhattan and Long Island than on the New Jersey or Richmond side. This arbitrary rule is practically spread over all the tonnage, so that freight which goes no farther east than the tide-water points in New Jersey, pays its share toward feeding the wharves of New York and Brooklyn.

This charge, at last, rests on the producer, or the ultimate consumer, and, in the competition for world trade, must be reckoned with. In the present agitation and study of rates, it cannot forever be overlooked, and some day the West will find out that the ship in the Port of New York may be reached without crossing the Hudson or New York Bay, but at the end of the track, and this arbitrary rule will have to go. Such artificial obstructions to free commerce cannot last in the world of to-day.

It cannot be denied as an economic proposition that the commodities of the continent, not originating or having an ultimate disposal on Manhattan or Long Island, should not be burdened with the cost of transfer. It also seems to be an economic axiom that a manufacturer, obtaining his raw material from over sea by ship, and from the interior by rail, and whose products are sent over sea or to the interior, in competition with the world, will not burden his business with the handicap of transfer across the Hudson or New York Bay, unless he receives some equal compensation by so doing.

The Borough of Richmond and the New Jersey side of the Harbor have undeveloped or partly developed water-front which is capable of doubling the commercial facilities of the Port at a comparatively small expense, and these facilities are at the end of the tracks stretching south and west across the continent, with thousands of acres of comparatively cheap, vacant lands adjoining the water.

New York has been possessed of great natural advantages from its beginning, but it has slept on them. It has heard, so often, that its harbor was the finest on earth, capable of accommodating the navies of the world, that it has not noted that the ships of the navies of the world have grown from 3 000 tons, 350 ft. length, and 20 ft. draft, to more than 20 000 tons, 600 to 900 ft. length, and 30 to 35 ft. draft; and that, of that great expanse of surface in the harbor and the two rivers, hardly more than one-third is available for major ships of the present day, not to mention the future.

New York's commercial facilities have grown like a wild tree—

Mr. Harrison. with no direction, no plan for the future—for years a football for politicians, and a medium for the transfer of spoil.

At the same time, the National Government has doled out, for the improvement of the main gateway of the country, a total sum of less than $20 000 000, including the cost of the Hell Gate and Ambrose Channel improvements, which is farcical in comparison with the appropriation for other and unimportant harbors.

The whole of Manhattan has grown in the same way—with no plan, no restrictions. To an outsider it has seemed to be a mad race to get as dense a crowd as possible in one spot. Increased land values have called for more floor space to earn taxes; more floor space called for more people to use it; more people called for more subways; more subways for more bonds, and therefore more land values, and so the circuit goes on.

The natural tendency of the people making up its population is to concentrate—a tendency advantageous to the real estate and building speculator, but deprecated by every expert in city building of to-day, and carrying with it evils which will be felt for years. No attempt has ever been made to prevent congestion. Every city move has been toward temporizing with the evil, or encouraging it. Therefore there are sweat shops in Fifth Avenue; fire problems; sewer problems; water problems; an army, greater than ever gathered on a battle field, rushed lengthwise through the town, packed in masses, twice a day.

Contrast this with the modern scientific work of building or remodeling, in the light of the twentieth century, in the old medieval cities abroad, for instance, in Cologne, Antwerp, Berlin, Hamburg, or even London. The motive is to spread out, to distribute the people, to restrict the population per acre, to prevent congestion at any point. Manufacturers are forced to an outer zone where they can have direct railroad connections. The houses of the working people are sanitary, and allow of decency and self-respect; they are usually detached, with plenty of open space; they are in the suburbs, far from the center of the towns, but their workshops are there too. There is land and building speculation, but the speculator is forced to follow the rigid plan, and must build what and how he is told. The market places are in convenient locations, connected by rail. If a maritime town, the wharves and docks are arranged systematically, to secure the transfer of freight with the least cost.

One disadvantage, which we will always labor under in the problem of terminal freight distribution and transfers between land and water carriage, as noted by C. W. Staniford, M. Am. Soc. C. E., Chief Engineer of the Department of Docks, in his report to the Mayor on European Harbors, is the size and weight of our freight cars. The European freight car is built to carry from 8 to 15 tons, and can be shifted easily by 3 or 4 men. It is transferred from one track to

another, or across the yard to tracks at right angles, by turning on a light turn-table. The great majority of the cars are flats, the freight being carried under canvas. Mr. Harrison.

Our usage has been toward heavier cars and loading. We look for economy in the long continental hauls by heavy train loads, and by so doing, we have reduced the cost per ton-mile to a figure which is startling to a European railroad man, but we cannot shift a car without an engine, or without giving up from 200 to 250 ft. of track for switches and clearances. Foreign cars can be handled on a pier or wharf in limited spaces, unloaded quickly by crane, and shifted away rapidly by man or horse power. A string of our cars in the center of a pier shed would be a nuisance, and, in most cases, impracticable, especially if the empties had to wait for power to be shifted or removed.

That this is the opinion of the steamship men seems to be proven by the fact that, at any time in the past, the New York Central tracks could have been turned into the piers on West Street, and the piers in Hoboken could be connected in a few hours to all trunk lines, but the tracks are not wanted.

It is true that most of the railroad terminal piers are equipped with tracks, and the cars are loaded and unloaded to and from lighters and other vessels, but these piers are part of the yard system. There is ample standing room for cars, and drilling engines are at hand at all hours.

A study of the track system required at the head of a railroad pier will illustrate the difficulties of handling cars from four running tracks on West Street in connection with a series of piers at right angles to the running tracks, and spaced, say, 350 ft. apart.

The writer agrees entirely with the recommendation of the Dock Commissioner that the pier line between West Twelfth Street and the Battery should be made a straight line, and further, he cannot see why the pier head at Battery Place should not be extended 200 or 300 ft. into the river.

An inspection of the charts will show that the present actual width between the 6-fathom contours at the mouth of the river is less than the same width at the Chelsea Piers.

To one familiar with the limited and crowded fairways of the great home ports of the European liners, through which they are skilfully handled, it is interesting to hear the argument that a waterway ¾ mile wide cannot be reduced without danger to navigation. Abroad there is a strict rule of the road, and it is enforced on water, as on land. We have regulated traffic on Fifth Avenue and other streets, and more than doubled their usefulness. We must do the same in the Hudson River. The relative importance to-day of longer piers exceeds the advantages of width of fairway. The recommendations of the United

Mr. Harrison

States Engineers to improve the channel of the East River, thus encouraging greater traffic in an already crowded waterway of much less width than the Hudson, should premise a favorable outlook for pier extension on the Hudson.

Mr. Cresson's assertion of the necessity of docking the great liners at Manhattan piers, and the alternative suggestion that long piers might be built to accommodate such traffic at Staten Island or South Brooklyn, savors very much of the provincial spirit which the writer has already decried in the attitude of Manhattan toward the port, as a whole.

Two of the largest, most successful, and best patronized fleets of liners in the world have always had their docks at Hoboken, and probably 40% of the trans-atlantic business by regular liners is handled on the New Jersey shore. There is room for several 1 000-ft. piers, with 35 ft. of water, north of Castle Point, and within easy access to the McAdoo Tunnels.

In the veracious history of Mr. Knickerbocker, it is related that on the occasion of the capture of Manhattan by the English, the inhabitants of Communipaw, by all smoking together, created such a fog that they were lost to view, and escaped discovery by the conquerors, who were deceived with the idea that there was only one side to the River and Bay.

As to the proposal for a joint classification yard on the Hackensack Meadows, with a tunnel to Manhattan, and a distributing elevated freight railroad along the west side to be used by the New Jersey roads, as well as the New York Central, the writer believes that, if it were practicable, it is inadvisable, in the light of modern civic study. Such a scheme would result in aggravating the congestion on Manhattan Island, perhaps to the improvement of real estate values, but certainly to the detriment of the economical service of the port. To a railroad man who knows what it is to handle a rush of delayed freight at the throat of a terminal yard, the problem of drilling a sufficient number of cars to pay fixed charges on the investment through the tunnel, or from the bridges, up the ramps, placing and removing cars from a hundred warehouses and piers, while keeping a running track open, is appalling.

If the City of New York is to stand the added fixed charges by general taxation, the structure may be used, to some extent, when desired by shippers, but the cost is certain to exceed the present cost by car floats.

The writer cannot see wherein the saving is between hauling from the car float piers as now, or hauling from a warehouse floor 20 ft. in the air, for distribution about the city.

A study of the yard room necessary for the comparatively small

volume of freight handled by the private enterprise at the Bush Terminal seems to condemn the practicability of this plan. Mr. Harrison.

The idea of a general classification yard on the Hackensack Meadows, and the freight tunnel to Manhattan, might be made practicable with certain modifications and additions. The writer begs leave to make a suggestion, only, in this direction.

Let there be a great classification and transfer yard in New Jersey. It should be equipped with ample platforms, electric cranes, overhead conveyors, and every known appliance for the economical handling of freight. Connected with it, there should be a series of warehouses—separate warehouses for each class of commodity, such as dry goods, hides and leather, hardware, machinery, furniture, wool, sugar, groceries, wines and liquors, and wheeled vehicles, and refrigerator plants for meat, poultry and dairy products,—all fitted with show-rooms having light, heat, electric transmission, etc.

Break bulk in this yard from the long-distance, heavy cars. Such freight as is not required to enter Manhattan, or can be sold by sample, as is done in Europe, may be stored in a space which will cost enough less than that of the same space on the Island to make a fairly good profit when the saved carting charges are considered.

Such freight as must be carried to Manhattan can be classified, not by 50-ton lots, but by cases, as mail is classified, and loaded on flats similar to those used abroad, with freight for each different section, or each separate concern, by itself, on these light cars.

Run through the tunnel, or tunnels, which need not cost more than one-half as much as tunnels for standard rolling stock, and, in Manhattan, build cross-lines connecting with two or more north and south lines of freight subways, with, say, two running tracks, and continuous sidings on each side, connected to running tracks by switches at short intervals.

In the sidings, at points desired by shippers, place turn-tables, so that a flat can be turned and pushed at right angles into the cellar of a building, and there unloaded and reloaded at the pleasure of the shipper. At convenient points let there be established general stations below the street level. The space above can be used for buildings. Build ramps from the streets for cartage to and from these stations. The stations could be of any size, occupying several blocks. Markets, similar to Smithfield in London, could be established in the same way at points of most usefulness. The gauge of these light lines need not, necessarily, be as wide as that of standard steam roads.

As for the transfer of freight to and from vessels on the Manhattan front, there is no better plan than that now in use, namely, by lighters in the slips outside of the vessels, and handling the freight to and from the hold by the ship's own tackle; no quicker, safer, or more economical plan can be devised.

Mr. Harrison.

It might be arranged that much of the coal delivered into large office buildings could be handled in this way, without ferriage and cartage through the streets.

In conclusion, let the City of New York rise to the appreciation of its metropolitan character, as the gateway of a continent, and include, and exploit in its interest, the whole area within a radius of 25 miles from Madison Square.

Let the banking, the buying and selling, the palaces of art and amusement, the town houses of the millionaires, the hotels, be on the Island. Every acre of its surface will be needed for these purposes in time.

Do your manufacturing, handling, and storage of heavy and bulky goods, and house your working people in the outer zones, where you can have a railroad back of the factory, and navigable water in front, and where moderate-priced, civilized dwellings, with light and air, can be built for the people. That way lies the path of modern thought and progress in city building.

State lines, except for taxation, are nothing. Manhattan as the center of trade, capital, amusement, and art, of a community such as this, would not miss the taxes from sweat shops and crowded tenements, and, in economy of doing business and handling commodities, could command the trade of the world.

Mr. Higgins.

CHARLES H. HIGGINS, M. AM. SOC. C. E.—This able paper deals with a matter of great local and even national importance. The problem of port facilities is fundamental. New York owes its very being to the wonderful natural advantages of its port. No petty rivalries or jealousies, as between individuals, companies, or even States, should be allowed to hamper the development of the resources of this port, if it is to be of the greatest service and maintain its present relative position.

A large part of the Port of New York is within the boundaries of the State of New Jersey. There, all but one of the great railways connecting with the productive West, have their terminals. There, freight intended for transhipment could be received directly on the pier without expense for lighterage. It is true that this latter transportation is said to be free within "lighterage limits," but all know that the expense must be borne, whether it is specified as a lighterage charge or is said to be "absorbed" in the freight rate.

As to New York City's daily supplies, they must cross the Hudson, and the solution offered by Mr. Cresson is attractive; however, a great tonnage of goods intended for transhipment reaches the Jersey shore by rail, and must continue to do so. If these goods could be transhipped directly from the piers, an immense saving would be made. No imaginary line, such as a boundary between States, should be allowed

to interfere with this natural flow of goods, if the most is to be made of the natural resources of the port. Mr. Higgins.

The North River has two shores. Manhattan Island, on the east, is a long ridge of Archæan rock, covered more or less completely with glacial drift. On the west side there is a similar ridge of like rock lying nearer the surface than that of lower Manhattan and not as deeply covered with glacial drift. This western ridge, extending from Castle Point, Hoboken—where ocean piers already exist—through lower Jersey City, once called Paulus Hook, in turn appears at Ellis Island, Liberty Island, Robins Reef, and near Constable Hook. It is true that this ridge, in the intervals between the prominent points mentioned, is or was covered by a few feet of water, but the old maps show the extreme low-water line extending along almost the entire distance; and, as said before, the rock, which in lower Manhattan is from 60 to 100 ft. below the surface, is found along this ridge at less than half that depth. It is this ancient metamorphic rock which, in this locality, must be reached in order to support heavy structures. This ridge, with deep water or soft, easily dredged, mud along its easterly side, is a great natural resource which should not be neglected because of a State boundary line, or because it is covered with 10 ft. of water instead of 10 ft. of sand, and it is for engineers to point this out. To laymen, perhaps anything above water is solid land and anything else is a natural waterway. The method of showing the land and water masses on maps tends to deepen this impression. Engineers, however, who design and build foundations, know that this is not the economic division. The depth, to a stratum capable of carrying great loads safely, is a controlling element in the cost of development.

This is not a discovery. For years, it has been known to engineers, and some others, and the thought can be traced back through scientific papers and reports for many years; but its significance has not yet been brought home to the public. This is due, largely perhaps, to the State boundary line, coupled with the fact that, until recently, Manhattan Island has offered the necessary facilities.

To bring about this development, the Federal Government must take a hand. Harbor lines must be changed, and new policies originated. New York's true advantage lies in this direction, for only by seizing all the natural advantages of the harbor, can it maintain its true position as a port.

M. Lewinson, M. Am. Soc. C. E. (by letter).—Mr. Cresson's meritorious proposition to relieve the congestion of traffic at the New York piers and provide accommodations for the new trans-atlantic steamers, which require longer piers, has only this disadvantage, that New York City, being already overburdened with taxes, may not, for some time to come, be able to raise the money Mr. Lewinson.

Mr. Lewinson. for such an undertaking. The delay in building the subways, so greatly needed, is caused by the same lack of funds. Furthermore, the condemnation proceedings, necessary in Mr. Cresson's plan, are tedious, very long, costly, and out of proportion to the real value of the property taken over. Nevertheless, New York City must have more piers and longer ones, in order to hold its commercial supremacy, and it seems to the writer that the project advanced by T. Kennard Thomson, M. Am. Soc. C. E., to extend Manhattan Island, should be given more serious consideration than it has received heretofore.

As the writer understands it, Mr. Thomson proposes to give to the city, free of cost, all the water-front of the newly made land, meeting the expenses of such an undertaking by the sale of lots along the new streets and avenues. That would add about 9 miles of water-front, which would be available for the building of new piers, and an immense revenue would be derived from them as well as from the taxes on the new land and buildings.

As this plan does not narrow the main channel, which is kept of the same width as The Narrows, and as the difference in the tide would be imperceptible, the writer is of the opinion that the War Department would not object to it, and the acquisition of Governors Island would not be difficult, as Congress is considering the sale of this island to the city.

By building the elevated railway along the westerly side of Manhattan Island, as proposed by Mr. Cresson, connecting it with the railroad subway proposed by Mr. Thomson, and further connecting this subway by a tunnel to Staten Island and thence by rail and tunnel to New Jersey, most of the advantages proposed by Mr. Cresson would be achieved.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE JUST VALUE OF MONOPOLIES, AND THE REGULATION OF THE PRICES OF THEIR PRODUCTS.

Discussion.*

By P. L. Reed, M. Am. Soc. C. E.

P. L. Reed, M. Am. Soc. C. E. (by letter).—This paper discusses a subject which everyone who follows political and social tendencies at all must realize to be among the most important and vital, and concerning which there has recently been, and will continue to be, much consideration and discussion. It is a comparatively new form of governmental activity, entered into with general reluctance and only because its difficulties seemed less than those which had grown up naturally around unrestricted industrial development. Mr Reed.

In the author's analysis and recommendations for the control of monopolies, he retains those incentives which make for individual efficiency and economy, for which free competition is usually given credit, while making fully available the collective economies which are credited to combinations and consolidations. At the same time the rights of the consumer are fully maintained. This is an ideal which is rarely attempted, and is undoubtedly attractive. It is believed that the general principles will be found sound—sounder than those commonly advanced, which imply either prices fixed by free or even compulsory competition, or, on the other hand, by the limiting or fixing of profits at an arbitrary percentage of the capital invested.

The writer, however, considers that to attempt to reduce these principles to algebraic equations inevitably brings in too many complications to lead to entirely successful results, and that, in addition to this difficulty, there are what seem to be defects in the author's

* This discussion (of the paper by Joseph Mayer, M. Am. Soc. C. E., published in *Proceedings* for January, 1912, but not presented at any meeting) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Reed. mathematical treatment to which attention should be invited in the discussion, in order that his main arguments may not be weakened.

In expressing algebraically the percentage of profit, the factors, y^n, in the numerator, and $(y^m + y^{m-1} +$, etc.) in the denominator, are introduced to make allowance, in determining the annual average rate of profit, for delays or postponements in the receipt or declaration of these profits or dividends, and they serve no other purpose. In this case, therefore, y is a function of the rate of interest which these profits might be expected to have earned for the investor had they been distributed earlier. This does not necessarily agree with the average annual rate of profit of the enterprise, and would only do so by chance, unless the profits were immediately reinvested in the same property. On the left side of the equation, therefore, y does not represent the same quantity as y on the right side, and it would seem that the expression would be much simplified and improved, if, for the unknown y on the left side, were substituted the same function of a fixed rate of interest such as the investor may be assumed to receive on his liquid funds, or the legal rate of interest.

As previously suggested, there are practical complications which would interfere so seriously with the use of such a formula as to make it of doubtful practical application, such as "going value," "depreciation," "obsolescence," and various suspense accounts. These factors would prevent to such an extent the exact determinations of the values a and A, as to make the consideration of interest on delayed profits an unreasonable refinement.

Again, under the heading, "Charging What the Traffic Will Bear," an equation is given (in the fourth paragraph) for the increase in profit due to a decrease in price with corresponding increase in quantity, assuming the cost per unit to remain constant. This equation is wholly independent of the "competitive" or "just" price, and is complete as it stands. The reason for bringing the latter in is not understood, since the most profitable monopoly price bears no relation to it. The most profitable monopoly price may evidently be more than, equal to, or less than, the competitive price, depending entirely on what effect a given change in price bears to the corresponding change in quantity. Still assuming the total cost per unit to be constant, the relation shown by the equation just referred to may be expressed in this way (each change in price to be relatively small): It is profitable to make a reduction in price when the ratio of a proposed change in price to the present profit per unit is less than the ratio of the resulting increase in quantity sold to the present quantity sold.

It is again suggested that such mathematical conclusions are of doubtful practical application. In this case the cost per unit rarely remains constant, usually lowering as the quantity or output increases.

Furthermore, it is exceedingly difficult to predict, even approximately, what change in quantity or sales will result from a proposed change in price. Mr. Reed.

Not only does it appear that the desired conclusions cannot be obtained by mathematical formulas, but neither can they be obtained by the application of even less fixed and definite rules. In attempting to determine such rules, the author is led into what seems to be an inconsistency, or circle of reasoning. Thus, the allowable average rate of profit of a monopoly should be the same as the average rate of profit in a similar competitive industry. The value of an existing monopoly shall be taken as the market value of its securities; but the average profit of such a monopoly, based on the market value of its securities, is already the same as the average profit in similar competitive industries. There is nothing to be done. We end where we started.

The author recognizes this objection, in the following:

"It may be claimed that this amounts to legalizing, for all future time, the present often unfair charges for monopolized products. This is not so. Where the charges of monopolies are known to be unfair, the investing public is aware of the fact and knows that they may be reduced by Courts or commissions. The market value of the securities of such a monopoly, and to some extent of all monopolies, is thereby reduced."

If the proposed rule for fixing the prices of a monopolized product is based on assumed previous knowledge of investors, Courts, or commissions of what fair prices should be, may not one ask by what rule the investors, etc., are to obtain their knowledge; and, if they already have a good rule, of what use is another which can only tell them what they already know?

It is believed, therefore, that the author's attempt to avoid physical valuations will not be generally considered successful, and that the attention which has been paid to such valuations to assist in the determination of fair prices is not without good reason.

Probably little more can be stated as a specific rule than in the words of the author:

"To fix and maintain such prices for all monopolized products as will make the average profits of every monopolized industry, * * * the same as those of the competitive industries at the same time and place."

The practical difficulties are plain enough, and perfect justice is unattainable, but it requires no special gift of foresight to realize that these difficulties must be met, that decisions must be reached, and that this will be working along the line of least resistance from the present stage of our industrial development.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

RETRACEMENT-RESURVEYS—COURT DECISIONS AND FIELD PROCEDURE.

Discussion.*

By Messrs. W. Newbrough, J. Francis LeBaron, and A. M. Strong.

W. Newbrough, M. Am. Soc. C. E. (by letter).—To one who is familiar with Government surveying, as done under the direction of the General Land Office, on the public lands of the United States, the title of this paper is somewhat misleading, and is also defective in that it does not mention that the paper relates to the public system of surveys, as above mentioned. This, however, is a minor matter, and Mr. Sweitzer is to be thanked for the paper, as too little is available on this subject. Mr. Newbrough.

It is to be regretted that the author did not give fully the reasons for making the surveys he speaks of, and state for whom the work was done. This would be enlightening, as the owners of lands in the far Western States are usually farmers and ranchmen who could not afford to pay for such extended work as he describes, nor does the ordinary surveyor generally have a chance to make resurveys with such full equipment. The reason for this is that a man (or a company) owning a few sections or parts of sections, say from 320 to 3 200 acres in a township, generally does not wish (or cannot afford) to go to the expense of running 80 miles of lines, covering about 23 000 acres of land, in order to locate his holdings; of course, this is not so if the land is valuable, but, at the present time, such is not usually the case.

Mr. Sweitzer refers to the bad or careless work on the old surveys, and states that this was due to the contract system in vogue in former years. The writer, having been engaged on Government contracts in years gone by, and having officially and privately retraced thousands

*This discussion (of the paper by N. B. Sweitzer, Assoc. M. Am. Soc. C. E., published in *Proceedings* for January, 1912, and presented at the meeting of March 6th, 1912), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Newbrough. of miles of lines of this character, personally and with his assistants, is in general surprised at the good work that was done. It is true that there are surveys in Wyoming, Utah, Montana, and California, notably those executed from 1876 to 1884, when contracts were taken by the Benson, McCoy, Woods outfit, which are valueless or very bad, but these are exceptions.

Since 1890, when the system of examiners was started, the work has been good. Lately, however, the General Land Office has abolished the system of contracts, and does the work itself. This has been going on for about two years, and it will take some time to prove whether it is better than the contract system with examiners.

However, as the paper treats especially of the surveys where corners are missing, the writer will confine his discussion more closely to that subject.

Retracements, as defined in the "Manual of Surveying Instructions for the Survey of the Public Lands of the United States and Private Land Claims,"* mean the determination of the true bearings and distances between the successive corners along the entire length of such a line; with details of the methods used.

The resurvey consists of a retracement, accompanied by the reconstruction of defective original corners and the establishment thereon of all the necessary new corners.† Consequently the resurvey includes the retracement.

On the subject of "Original Surveys," under which head Mr. Sweitzer quotes several Acts of Congress, it may be well to mention that the "Manual" gives the whole history of the establishment and maintenance of the United States system of public surveys, including all the Acts of Congress passed in relation thereto.

He also states that "any resurvey, in order to be legal, will have to relocate the original Government corners in their original positions." This is the case when a private surveyor makes the resurvey, but not when it is made by the Government, as is shown by the thousands of resurvey plats now on file in the various land offices. In many cases the new survey corners are a few miles from the old ones. The reason these are held to be legal is that the lands resurveyed still belonged to the United States, and the resurvey virtually is the original. Any patented lands are marked in their original positions by monuments and thus platted on the resurvey plats.

The above requirement is not absolutely insisted on by the Courts when it is manifestly unreasonable, as witness the case quoted on page 8 of the pamphlet issued by the General Land Office entitled, "Restoration of Lost or Obliterated Corners and Subdivision of Sections."

* Obtainable from the Commissioner of the General Land Office, Washington, D. C., or from the Superintendent of Documents.

† Manual for 1902, p. 79.

"In the case of an erroneous but existing closing corner which was set out of the true State boundary of Missouri and Kansas, it was held by the office that the surveyor subdividing the fractional section should preserve the boundary as a straight line." Mr. Newbrough.

The foregoing pamphlet is valuable, and should be obtained by everyone concerned in the work designated by its title. While Mr. Sweitzer's paper gives methods for handling large areas, this pamphlet will usually suffice to retrace or resurvey any small portion without re-running the whole township. In addition to this, its rules are very practical. For instance, suppose the corner to Sections 14, 15, 22, and 23 is missing. Suppose the quarter corner to Sections 15 and 22 is in place, and the surveyor begins there and runs a random line east. At 1 mile he finds nothing, at 1½ miles nothing, at 2 miles nothing, and the same at 2½ miles, which brings him to the range line. Now, instead of running farther east, he must run north and south to try to find a range corner. The reasons for this are explained in the pamphlet. In the State of Wyoming this pamphlet has been incorporated bodily into the State Laws.

Mr. Sweitzer quotes several decisions, some of which relate to surveys other than those here treated of, but he makes no mention of what may be called the "law of acquiescence," or possession undisturbed for a number of years. In Wyoming, by law, this time is 10 years; in other States, other times are stipulated. This law gives the surveyor more trouble than nearly all the others, and this is caused by its enforcement by the Courts. Sometimes it is held to be good; at other times it is not. It seems to be elastic. Strange as it may seem, it is sometimes held good by the General Land Office. Witness the case of T. 24 N., R. 119 W., 6th P. M. This township, on the ground, by the original survey, had the following corners in it in the year 1904: SW. corner of Section 5 (¼ corner to Sections 5 and 8), SE. corners of Sections 8, 17, and 20, and some others which do not relate to the case. On the ground, the sections of the north tier were ¼ mile too long, north and south. The plat in the land office showed the sections 1 mile long, or correct. Each 40-acre tract had on the ground an excess of acreage of about 40 acres. A road along the south boundary of Section 5 had been constructed soon after the survey was made, and extended clear across the section. If strict rules had been followed, this excess ¼ mile would have been distributed in the north and south tiers of sections lying east of the quarter corner to Sections 5 and 8. All the land in Sections 3, 4, and 5 had been patented and cultivated for years, and each settler who was fortunate enough to have this excess of 40 acres claimed it undisputed for years. In 1907 the Government made a resurvey of this township, and sent special examiners out in addition to the regular deputy. The result was that the road was presumed to be correct, according to the original survey, having been there for years, and each claimant got his 40 acres of excess for nothing.

Mr. Newbrough. The writer should have mentioned that, while there were no other corners, there were several old fences which also helped this decision. There were no corners on the east boundary of the township, except the SE. corner.

In general, the law that makes the corners correct and unchangeable is a good one. When the ground is first surveyed, it is generally worth about $1.25 per acre. A man files a homestead or desert claim on such land; it is still worth no more, and if the closing on a section is within 50 links or so, not much acreage is taken from or granted to the settler, so that no harm is done. In time the land is improved—possibly sold to others—and becomes valuable. No harm has yet been done, because each man has known just what he was buying. It makes no difference whether the final owner has 155 or 160 acres. He has lost nothing.

The correction of errors by the Coast Survey causes no one any trouble, and so it is reasonable that they should be corrected.

This law practically applies to a lot in a town, as well as to the Government corners. The purchaser gets the lot where the original lot stake stood, whether this gives him 50, or 49.7, or 50.2 ft. Averaging, in resurveys, is only for the purpose of trying to equalize matters, and an original town stake will disarrange the most careful averaging, or even correct resurvey, every time. As Judge Cooley says: "It is not where the monument should have stood, but where it stands that governs." The method of correcting erroneous surveys on Government lands is by making a resurvey, and this is done quite frequently. One Act of Congress, five years ago, ordered the resurvey of about 400 or 500 townships in Western Wyoming, and the surveyors have been at this work ever since. Much of this land did not need resurveying, but that is another story.

As Mr. Sweitzer says, when pits have been dug in the grass-covered prairies of Kansas and Nebraska, they can be found, but when a surveyor makes a mound of earth in a clear, sandy country, and places four pits around it, in 12 months, the pits are filled with sand and the corner is lost. This has been the case in Wyoming and Utah. Mr. Sweitzer's remarks on bearing trees are valuable.

The author should have stated that his "Township Partly Surveyed" could be fixed up if the SW. corner was in place or could be located, otherwise it could not. In his "Township Never Surveyed," he assumes that the exteriors are in place, or can be located. Usually, it has been the fate of the writer and his assistants to find some corners in place on the boundary of the township and some on the interior, but, with both combined, there were not enough to enable one to follow the author's method in full. Generally, the writer has had to run from interior corners to help locate exterior ones, going into the township in discussion and the adjoining ones, and then has frequently had to use much judgment in placing them. In such a case as this it would be well to study the pamphlet previously mentioned.

Exterior corners are supposed to be located in two directions only, as the township and range lines are the most important, and yet every missing corner should be replaced by checking from every possible direction. In doing this it will generally be necessary to run interior lines, and then it should not be necessary to re-run these lines when following Mr. Sweitzer's method. Care should be taken on this point. Mr. Newbrough.

The method given for an observation on the pole star at any hour (and taken at about sundown) is quick and accurate. Some years ago Mr. Baldwin, of the U. S. Geological Survey, suggested to the writer that when using this method, it would be well to make a scale on a narrow board, assuming a radius of about 300 ft. This gives about 0.1 ft. to the minute, which, of course, can be subdivided clearly enough to read 5″. The board is continually carried in the field, and is used as the mark when taking an observation. By making this board about 8 ft. long, it answers for the mark and for turning the azimuth of the star. The writer has found that with care the observation can be taken within about 15″ on an instrument graduated to minutes. It is noted that Mr. Sweitzer takes his mark about 30 chains distant, but in his examples he reads his instrument only to minutes. It is hoped that, in his closing discussion, he will give the reason for this. One minute in 300 ft. is about 0.1 ft., and the writer sees no reason for taking a mark farther away, except possibly that it may be a natural object which may be of considerable size.

In Wyoming and Utah surveyors make great use of direct observations on the sun, and by taking four can generally come within about a minute. To one who is accustomed to these, the calculation is very rapid.

One of the most valuable features of this paper is the table for running east and west lines, which is a great improvement over the secant method.

J. Francis LeBaron, M. Am. Soc. C. E. (by letter.) This is an excellent paper, and should be in the hands of every civil engineer having field work to do in that part of the country covered by the United States system of Public Land Surveys. Mr. LeBaron.

Nearly every engineer who comes from the original Thirteen States, where this system is not in use, appears to be utterly ignorant of the fact that corners set by the U. S. Surveyors under this system are immovable and non-changeable, and when employed to re-survey a section line and re-set a lost section corner, they proceed to do the work without first obtaining copies of the original field notes, or the original township plat, without which they cannot make a legal re-survey. These notes and plats can be obtained only from the U. S. Surveyor-General for the district in which the land is situated, and not from the Register or Receiver. The latter will furnish a plat, but it is correct only as regards areas and has no courses and generally

Mr. LeBaron. no distances marked on it. The plats from the Surveyor-General's office, on the contrary, contain all these data.

Too often the writer has seen surveyors re-run section and township lines without any plats at all, and without any copy of the original field notes, assuming every section line to be exactly 1 mile long and running true north and south, or east and west. Then, when the surveyor's most accurate steel tape measurements and transit lines failed to locate the corner on the fence or blazed line, he would establish a new corner and assure the land owner that his corner was absolutely correct, because so much care had been taken in the work. The writer has found corners of this kind set up in fields as much as 70, 80, or 100 ft. from the true position, and the whole neighborhood in a turmoil. It never seems to occur to these "surveyors" that they may be taking from or adding to the land of the adjoining owner.

It is customary for most cheap surveyors to establish corners in this way, never checking up from the opposite direction, because they say their clients object to the expense. In this they are countenanced by the majority of lawyers, who also show a surprising ignorance of the law of surveys. The writer has known a lawyer to counsel a client not to pay the surveyor's bill because he had gone to an opposite corner, a mile away, and run a check line south to fix the provisional corner which he had set by running from an established corner north. As the two corners came about 60 ft. apart, the true corner was set by proportional distances, and three of the four witness stumps were found. The trees had all been cut off, so that no blazes could be found at the corner or on any of the lines. The result threw the client's house on the wrong side of the line, and the lawyer, who had employed the writer, advised his client not to pay the bill, saying that the writer had done him no good, but rather harm, and had spent three-quarters of the time in surveying other men's land, alluding to the check lines, which it had been found necessary to run.

Lawyers, almost invariably, will insist that the survey shall be started from the first point named in the description in the deed, entirely oblivious of the Courts' rulings that this point is of no more dignity than any other in the description, and they generally presume to instruct the surveyor as to how the work should be done, somewhat as follows:

"I want you to start from the beginning corner, as given in the deed, run the exact course and distance, and set a stake there. That is all you have to do. It will not take you long. I suppose you make an allowance for the variation of the needle. The needle, you know, does not point exactly north, and you must make an allowance. This deed reads 'due north' so many chains. Now does that mean true north or the way the needle points? I suppose when you chain downhill you make an allowance, don't you, because I think the distance wouldn't come right if you didn't? I don't know how much you allow, but I suppose you have some custom about it. You see,

Mr. LeBaron.

this deed says so many chains and links, so you must measure it with a chain and links, and not any other kind of a measure, or I am inclined to think that the Court would reject your survey."

The writer has actually had these instructions given to him on several occasions, although the first sentence is directly at variance with all the decisions of the Courts, which are that marked lines and corners must govern, and not courses and distances. Every honest surveyor knows that courses and distances are only aids to help him find the true corner, and if the corner is lost it can only be re-established by running lines from all well-established corners and proportioning the errors. The legal mind, however, is peculiar.

The writer has read this paper with much interest, and heartily approves of it, but he is somewhat surprised that the author does not mention the pamphlet published by the U. S. General Land Office, entitled, "Instruction for the Re-establishment of Lost or Obliterated Corners." This is official, and can be obtained free from the Commissioner of the General Land Office at Washington. In addition to the books mentioned by the author, "Dunn's Land Laws and Legal Decisions,"* will be found invaluable, and for several years *Engineering News* published a column of "Legal Decisions," which are very useful both to the surveyor and the engineer. Every chief of party on railroad location in the Public Land States should be provided with these books in order to compute correctly the land taken from private owners for right of way, and also to enable correct maps to be made.

As a general thing, railroad maps show the township and section lines running straight for scores of miles, and every section exactly 1 mile square, whereas, as a matter of fact, it is only in very exceptional cases that such lines are straight. On the contrary, almost every section line will vary in course and distance from every other, and the section just south of every township line will be found to fall short or exceed the normal length to a considerable degree, as the law of the Public Land Surveys provides that the surveys of the sections in a township shall commence at the southeast corner and proceed north and west. The township lines having been previously run and the section and half-section corners set on them, the subdivision of the interior sections proceeds until the north and west township lines are reached, when it invariably happens that the closing lines will fall short or over-run from a few links to one or several chains, and the law directs that this deficiency or excess shall be thrown into the last half of the section.

When the course of the last mile does not strike the corner of the section previously set on the township line, it is very often found that double corners have been established, one set for sections north or west of the township line and the other for sections south and east. Therefore, it is absolutely essential for the engineer to have copies

* Engineering News Publishing Company, New York.

Mr. LeBaron. of the original survey field notes, and run out each section through which the railroad passes, in order to compute the area of the fractional sections taken by the right of way, etc., as the distance measured on the ground between the section corners will seldom agree with the distance recorded in the field notes. The draftsman must have these notes in order to make correct maps.

As a general thing, however, all railroad maps are drawn with perfectly straight and regular section lines, ignoring all double corners and all excess or deficiency adjacent to the township lines. It is much easier for the draftsman, saves time, and looks so much better! Then people wonder why two maps never match by the section lines. The general method is to locate a section corner now and then, when the line runs near it, and, from these, lay off an exact checker-board of sections, without any reference to the field notes of the original survey or the official plats of the Surveyor-General's office. The result is confusion.

Mr. Strong. A. M. STRONG, ASSOC. M. AM. SOC. C. E. (by letter).—This paper calls attention to a subject which is of great importance in the growing Western States and of which the general public and many engineers seem to know very little. The rules governing retracement-resurveys, as outlined by the author, have been found necessary in order to hold to definite boundary lines after corners set on original surveys become destroyed. They should be followed on all such surveys, but many engineers and surveyors either do not know them or pay no attention to them. These rules apply not only to the retracement of section and township lines, but to the subdivision of the sections into smaller tracts, townsite surveys, and to many other classes of work.

Mr. Sweitzer touches on the principle of *pro rata* or proportional measurements, which many seem to find very hard to understand. On the old Government surveys a chain 66 ft. long was used on level ground and one 33 ft. long on rough ground. These chains were made up of 100 or 50 short lengths of wire connected by links. In the field these links became worn and stretched out of shape, thus lengthening the chain, or the wires became bent and the links kinked, thus shortening it. Each party was supposed to carry a new standard chain, and the old instructions read: "The chain in use will be compared and adjusted with this field standard each working day." In practice, one standard had to do for several parties, and adjustment was made only at long intervals. Even where the original chaining was done with reasonable care, as was the case under many of the contracts, a considerable difference will be found in retracing with a standard steel tape. The rule that "the length of such lines as returned * * * shall be held and considered as the true length thereof," simply means that the chain used on the original survey is to be considered the standard measure for that particular piece of work.

On minor Government surveys, such as mineral lands, and on

right-of-way filings over Government lands, the instructions from the General Land Office read: "When a * * * line * * * intersects a section line, give course and bearing from the point of intersection to the corner of the public surveys at each end of the half mile of section line so intersected." It was long held that all such courses and bearings must be reported as given in the original field notes. In many cases this necessitated the filing of notes in which the measured distances were proportioned to fit the original notes. Later, this rule was changed to allow "the bearings and distances to be reported as found," thus acknowledging the differences which would be bound to occur except under work of the most expensive class. A fruitful source of trouble is where rights-of-way on public lands have their location in sections computed from a few ties. Later, when the land is located and improved, it is found that the ditch, pole line, railway, or whatever it may be, is not occupying the land reserved for it by the Government. Mr. Strong.

In many districts only a few of the original corners can be found, and the common practice of starting from the nearest of these and laying off the land with true bearings and standard measurements results in as many sets of lines as there are corners from which to start. A given tract of land can usually be surveyed in less time in this way than by making a correct retracement-resurvey, and unless the owner of the land is well posted on correct methods, he will naturally go to the man who will do the work in the shortest time. As a result, many unnecessary disputes arise, for which the surveyor is mainly to blame. The permanent establishment of property lines so that fences and other improvements can stay where they are placed is usually worth more than a little land, and the extra time necessitated by the correct method is worth its cost.

Perhaps a few cases which have come to the writer's observation will illustrate some of these points. A certain township was surveyed in 1856, light wood stakes being used for the corners. It was partly settled in the late Sixties in large holdings. In late years these large holdings have been cut up, and a considerable increase in values has called attention to property boundaries. Recently, a number of retracement surveys have been made, and the only corners which can be found are in some rocky land along the northern and southern township lines. The surveys were made by different parties using one or another of these few corners as starting points and giving the land full measurement. It was soon found that in the center of the township there was an overlap of about 200 ft. between the surveys starting from the north boundary and those starting from the south. Practically, not one of the old fences or roads would fit either set of lines, and even the location of the lots in the village were in dispute. A proper retracement survey, connecting all the existing corners and the oldest fences and tree rows, which were supposed to have been built

Mr. Strong. or planted when more of the corners were in place, showed that by using a chain length of 65.34 ft. every point could be checked. The result is that no one is satisfied, and each property owner is inclined to believe that the survey which comes nearest to fitting his lines as he has them fenced, and still gives him his full area, is the correct one. The Courts will have to settle the disagreement between the different surveyors.

In another case in which the land was surveyed at about the same time, and settled under similar conditions, there now remains a township corner and three interior section corners. A number of recent resurveys have been made, some using one and some another of these corners as starting points, with the result that every property line in the district is unsettled. One of these surveys was made in connection with a very large water-development project, and right-of-way deeds were made out from it, describing the lands by lines joining points on the boundaries of legal subdivisions. A proper retracement survey, joining all existing corners and old land marks, showed that while the distances were about correct, the lines differed from the true meridian by nearly half a degree. The right-of-way deeds included valuable lands which it had never been the intention to convey.

In a desert valley surveyed in 1854 the corners were marked by oak stakes, charred on the points and set in earth mounds. It has been found within the last few years that there is water below the surface and the valley is being settled. The first settlers brought in a surveyor to give them the lines on the land. He located a few of the original corners, but as he was not able to make them fit exactly with the field notes, he claimed that they must be incorrect, and, starting from a standard parallel, made what he claimed to be a correct resurvey of the valley. The writer found that the length of the original chain must have been about 66.5 ft., and, working on this basis, has been able to find some remains of the majority of the original corners. In some places they are as much as 300 ft. from the corners as set for the first settlers.

An engineer engaged in building a short branch railway had occasion to set the corner for a certain piece of property, and it differed so much from the accepted lines that the owner would not sign the right-of-way deed. When the county surveyor was called in, the railroad engineer explained that his work was tied in to a well-established corner on the township line 5 miles away, and he was positive that he had the correct point for this corner to within at least a couple of tenths. He probably still thinks that the county surveyor's statement, that this method of setting a corner might give a point as much as 200 or 300 ft. from the true one, showed that this surveyor was incompetent.

In each of these cases a little attention to the established rules in the first place would have saved much expense and trouble, to say nothing of the feelings of the engineers involved, and these are not exceptional cases by any means.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

ROAD CONSTRUCTION AND MAINTENANCE.
An Informal Discussion.*

BY MESSRS. GEORGE W. TILLSON, THEODOR S. OXHOLM, A. W. DEAN, W. D. UHLER, ARTHUR H. BLANCHARD, WILLIAM H. CONNELL, LINN WHITE, AND CLIFFORD RICHARDSON.

FILLERS FOR BRICK AND BLOCK PAVEMENTS.

GEORGE W. TILLSON, M. AM. SOC. C. E.—The materials now being used for block pavements are stone, brick, wood, and asphalt, and the matter of filling the joints is of great importance. The object of the filling is to make the surface water-proof, prevent undue wear of the individual blocks, and preserve the continuity of the pavement. Brick and stone produce a noisy pavement, and, for these types, the filler should tend to reduce this noise, if possible. At present, specifications call for joints in such pavements to be filled with sand, tar and gravel, coal-tar pitch, or other bituminous material, and cement grout. Mr. Tillson.

Naturally, when the first crude pavements were laid, a cheap and available filler was used. This led directly to the use of sand, which gave fairly good satisfaction for those times, when it was not deemed necessary that the pavement should be water-proof. When an attempt was made to improve the pavement, however, the blocks were made of a more regular shape and laid on a concrete foundation. From a sanitary standpoint, the pavement was required to be water-proof, and a filler other than sand was sought. The material decided upon was gravel, ranging in diameter from ¼ to ½ in., the interstices being filled with coal-tar pitch. This method was used in London in 1869, in Manchester previous to that time, and in New York City by the Dock Department in 1881. When brick pavements were first introduced, sand was used in the joints, followed later by cement grout and coal-

* At meetings held January 19th and 20th, 1912. As much of this discussion as possible is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Tillson.

tar pitch. The spaces between the blocks of the old cedar pavements, so much in vogue in the Central West between 1880 and 1890, were filled generally with sand, but sometimes with tar and gravel, the latter materials being used when the blocks were laid on concrete. The joints between the blocks of the modern wood pavement have been filled with sand, cement grout, or with coal-tar pitch, or some other bituminous material. The filler for asphalt blocks has almost invariably been sand, though sometimes, in relaying old blocks, the joints have been filled with asphalt.

Stone Pavements.—The first blocks used for pavements were of stone, and the joints were filled with sand, as has been stated; but such a filling should only be used for a temporary pavement. A sand filler does not preserve the edges of the blocks from undue wear, and consequently they soon round off, presenting a cobble-stone effect to travel. Water soaks through the joints during rain, dampening the foundation. Urine from horses also saturates the sand at times, giving off unwholesome odors when it evaporates. When concrete foundations were first introduced for stone pavements, it was realized that sand joints would not do. The tar and gravel joints previously referred to were then adopted, the idea being that the gravel would keep the blocks in place, and the tar, filling the spaces between the gravel, would render the entire joint water-proof. Theoretically, this was undoubtedly true, but, practically, there was often enough fine gravel to prevent the tar from filling the entire joint; or the tar itself, as well as the gravel, would become cold, thus preventing a free flow, the result, in many cases, being a joint which was far from watertight. Then, after some time, the upper part of the joint would wear, sometimes to the depth of nearly 1 in., so that the edges of the blocks would wear off, producing what is known as the turtle-back effect, which is almost always seen in old pavements of that character. To use gravel of such a size as would permit the free flow of the tar made it necessary to have wide joints, which was also conducive to the undue wear of the blocks, often making a rough and unsatisfactory surface, even when the blocks themselves were fairly good.

Two improvements over the tar and gravel joint have been used: a straight coal-tar pitch or some other bituminous compound, and Portland cement grout. To make the pitch joint satisfactory, it is necessary to lay the blocks close, even stone to stone, and dressed so that there will be no excess spaces to be filled. With narrow joints, the pitch will hold the blocks in a stable position and also prevent the direct transmission of the impact of traffic from one block to another. A stone pavement is bound to be noisy, but one laid in the foregoing manner is thought to be as free as possible from this defect. The blocks being laid close prevents undue wear on the edges, such as seen with tar and gravel or sand joints. A notable instance of a

pavement of this character, laid during 1911, can be seen on Fourth Avenue, Borough of Manhattan, New York City. Here, special requirements were made for both the pitch and the blocks, those for the latter being probably more stringent than for any work of a similar character in the United States. The requirements were lived up to, and the result has been a highly satisfactory pavement. Mr. Tillson.

Worcester, Mass., was probably the first city to make use of the cement grout joint. The spaces between the blocks were first filled with stone screenings and then poured full of the grout. The result was very satisfactory. As the blocks were gradually made better and therefore laid more closely, the screenings were left out entirely, and grout alone was used. There are advantages and disadvantages in a joint of this kind. It makes a smooth and even pavement, and one that is easily cleaned. It presents little resistance to traffic, and brings the wear of traffic vertically on the top of the blocks, so that the pavement is very durable. As the joints are filled full of the grout, which wears down evenly with the surface, the pavement itself becomes smooth and slippery under wear, both on account of the smooth surfaces of the blocks and because of the lack of joint depressions to give foothold to horses. It is also extremely necessary that the grout should become thoroughly hard before any traffic is allowed on the pavement, otherwise the blocks will be loosened and the permanent set prevented, so that the filling becomes little, if any, better than sand. Pavements thus laid become practically continuous, giving off a metallic noise under traffic. The hardened grout, being a good conductor of sound, transmits the noise readily from block to block. Where the grade is flat, however, and the street is kept free from traffic until the grout has thoroughly set, the pavement will be very satisfactory. It is the smoothest form of stone pavement that has been laid in the United States. Most specifications provide that the street shall be closed to traffic for a period of 7 days after the grout has been poured, in order to give the latter time to set. A pavement of this kind presents great obstacles to plumbers or subway men. It is exceedingly hard to open, many of the blocks breaking rather than separating from the next adjacent ones, thus causing a great deal of waste. It is difficult, too, to repave an opening properly, as traffic forces itself on the freshly grouted blocks, thus breaking the bond.

The advantages of a pavement of this type are that it is smoother, more durable, and more easily kept in shape than any other; the disadvantages are that it is more slippery, noisier, and harder to repair. The specifications for cement joints in various cities are much alike, but those of Newark, N. J., are perhaps the most elaborate. They alone, however, provide that the grout shall be kept on the surface of the blocks even with the highest part, and that the mixing shall be varied so as to make the grout vary in hardness according to the hard-

Mr. Tillson. ness of the particular stone used. The following is quoted from the Newark specifications:

"After the pavement has been brought to a uniform surface, Portland cement grout shall be poured into the joints until it appears on the surface. The grout shall be broomed into the joints, if necessary, to fill the same, and the operation must be continued as the grout settles until the joints are thoroughly filled flush with the surface of the blocks, immediately after which the entire pavement shall be broomed to a smooth surface, sufficient grout being applied to bring said surface even with the highest part of any of the blocks. The blocks shall be wet by sprinkling immediately before applying the grout if the condition of the atmosphere requires this precaution to be taken.

"The cement grout shall be composed of one or more measures of the best quality of freshly burned Portland cement to not to exceed one measure of clean, sharp sand. The mixture to be employed for any piece of work shall depend upon the hardness of the granite used, and this mixture shall be ascertained by sufficient experiments to give a grade which will be of such a strength as to wear down uniformly with the granite used. In the mixing of the cement and sand, clear water shall be used, to give the proper consistency.

"The grout must be mixed for this purpose in a box about four (4) feet eight (8) inches long, thirty (30) inches wide, and fourteen (14) inches deep, resting on legs of different lengths, so that the mixture will readily flow to one corner of the box, the bottom of which shall be six (6) inches above the pavement. The mixture must be removed from this box to the street surface with scoop shovels, all the while being stirred in the box as the same is being emptied. One such box to be provided for each ten feet of width of roadway. The work of filling should thus be carried forward in line until an advance of fifteen to twenty yards has been laid, when the same force and appliances shall be used to regrout the same space in a like manner, excepting that the proportion of the mixture shall be two parts Portland cement to one part sand. To avoid the possibility of causing the grout to become too thick at any point, there should be a man with a sprinkling can, the head perforated with small holes, slightly sprinkling the surface ahead of the sweepers. To insure the penetration of the grout into the joints of the pavement there shall be used, in addition to the brooms, a squeegee scraper, 15 to 18 inches in length, on the last application of the grout.

"Within one-half to three-quarters of an hour after the last coat has been applied and the grout between the joints has fully subsided, and the initial set is taking place, the whole surface must be slightly sprinkled and all surplus mixture left on the top swept into the joints, bringing them up flush and full. After the grouting is done and a sufficient time for hardening has elapsed, so that the coating of sand will not absorb any moisture from the cement mixture, one-half inch of sand shall be spread over the whole surface, and in case the work is subjected to a hot summer's sun, an occasional sprinkling sufficient to dampen the sand should be followed for two or three days.

"After the grouting is completed the streets shall be kept closed and no carting or traffic allowed until at least seven (7) days have elapsed on any portion of the street grouted, and the face of the pavement shall be kept moist if the condition of the weather requires this precaution. The contractor shall erect sufficient and well constructed barricades, and furnish watchmen at all times, if the same shall be necessary, to insure that this precaution in regard to the prevention of traffic or carting is complied with. Should the bond between the blocks become broken for any reason, the joints at such places shall be cleaned out, even if it is necessary to take up and relay the blocks, and such parts so taken up and relaid shall be regrouted and rebarricaded." Mr. Tillson.

With the improved stone specifications, most cities are using the cement joint at the present time.

Wood Pavements.—The first joint filling in modern wooden pavements was sand. Afterward, Portland cement grout and bituminous fillers were used. The speaker has always used sand. Wood blocks are so regular in form that they lie closely together in the pavement, and need a filler only to keep them in place. It may be said that with a sand filler the pavement will not be water-proof, but experience seems to demonstrate that the blocks, under traffic, soon mat together, making a surface which is practically continuous. The speaker recently examined a pavement of this character which had been subjected to light traffic for some 7 or 8 years, during which time it had been perfectly satisfactory. The sand should be fine, and thoroughly dry when applied, so that the joints will be entirely filled. Should oil at any time exude from the blocks, the sand will assist in absorbing it.

Where a cement grout is used, it is made of equal parts of fine sand and the best Portland cement, carefully mixed, and swept into the joints until they are completely filled. The pavement is then covered with sand and the grout should be allowed to set for at least 7 days before the pavement is used. If the blocks are disturbed before the grout has set, the filling becomes of no more value than sand, and, as far as its absorptive properties are concerned, is even of less value.

Coal-tar pitch, asphalt, and special bituminous fillers are also used quite extensively by different cities, the idea being to make the pavement water-proof as well as to provide for some slight expansion of the blocks. Where such fillers have been used and excessive bleeding has occurred, much of it has been attributed to the bituminous filler.

In addition to filling the joints between the blocks, most specifications provide for expansion joints along the curb, and, in some cases, for joints across the street at intervals of about 50 ft. These joints are generally 1 in. in width, and are filled with either pitch, asphalt, or some similar material. Where the blocks are thoroughly treated with proper water-proofing, the cross-joints do not seem to be necessary.

There seems to be considerable difference in the practice of cities regarding the joint filler for wood pavements. For instance, the

Mr. Tillson. specifications of St. Louis, the Boroughs of Manhattan and Brooklyn, New York City, and those adopted by the American Society of Municipal Improvements call for sand; those of Detroit, for sand or paving cement obtained from the direct distillation of coal-tar, or any other approved composition; those of Indianapolis for an asphalt filler prepared from such asphalt and flux, if the latter is needed, as will conform to the specifications for asphalt paving cement; it must not be brittle at 32° Fahr., nor flow at 120° Fahr., it must adhere firmly to the blocks, and be sufficiently pliable to permit expansion and contraction; and those of Newark require a filler made of 1 part Portland cement and 2 parts sand.

The specifications of Westminster, England, require the following: All pavements shall be laid so as to leave as little space as possible at the sides and ends of the blocks, and, on completion, a mixture of boiling pitch and creosote oil, in approved proportions, shall be poured over the whole surface, be well forced into the joints, and be scraped off with wooden or rubber squeegees, the joints being thoroughly filled. The pavement shall then be finished with fine sand and cement grout in equal proportions, brushed over, and have a top dressing of approved gravel which will pass a ½-in. mesh, and be free from sand.

The specifications of the Organization for Standardizing Paving Specifications permit pitch, asphalt residuum, or sand, the latter being recommended for heavy traffic.

Brick Pavements.—As already stated, sand was used for a joint filler in early brick pavements. This, however, did not give general satisfaction, especially when the bricks were not laid on concrete, as it did not protect the joints from wearing. In many places, however, where the traffic was not heavy, sand has been used successfully. The following is taken from a letter received recently by the speaker from a prominent official of a large city in the Southwest:

"We have been using sand as a filler for the joints, for the reason that the bitumen filler is chilled before it gets to a sufficient depth between the blocks to serve its purpose. Where a dry sand has been used, the results have been entirely satisfactory. This applies not only to streets with heavy traffic but to those where the traffic is light. However, I have insisted on there being some stable header along the pavement; otherwise I would recommend the bitumen filler instead of sand.

"With the first brick pavements laid in this city, sand was used as a filler, and the results were satisfactory. The sand-filled pavements, after twelve years of service, look better than many of the grout-filled pavements."

When it was learned that the sand filler did not give good general satisfaction, both Portland cement grout and a bituminous filler of some kind were used. The advantages of the bituminous filler are that it decreases the noise and also takes up the expansion of the bricks.

It does not protect the edges of the bricks from wear, however, and they round off under traffic, making the pavement rough. Some cities, however, now use the bituminous filler to a great extent. Mr. Tillson.

The Portland cement grout filler is desirable, because, by filling the joints between the bricks even with the tops, the joints become part of the pavement, and, if properly made, are of practically equal strength with the brick, so that the pavement as a whole wears smoothly. In practice, however, two faults have developed with the cement grout filler: as it makes the pavement continuous, it expands, sometimes to such an extent that the pavement blows up with a loud report when the expansion is longitudinal, and sometimes, when it is transverse, the curb is displaced or broken. Often, when the expansion is slight, it apparently raises the pavement up from the sand cushion, so that the traffic causes a disagreeable rumbling noise.

There was a case of this kind in Brooklyn where the noise was so great that the pavement, although in good condition, was taken up and asphalt was laid in its place. Afterward, however, another brick pavement was laid in the same manner, but with more care, and there was no trouble whatever, although no expansion joints were used. By the observance of more care in the construction, the rumbling spoken of has been practically overcome, but expansion joints along the curb have been considered necessary. These joints are filled with coal-tar pitch or some other bituminous material.

Another defect in the early grout-filled pavements was that they often cracked and sometimes broke down, with the apparent failure of the grout in considerable portions of the street, while other portions remained intact. This occurs to some extent in grout-filled stone pavements. Its cause is uncertain; it is possibly the lifting of the pavement under expansion, as already mentioned, or possibly the unequal mixing of the cement and sand for the grout. The following is quoted from the letter previously referred to:

"I find that many of the brick pavements in the Western cities are disintegrating, due to the stresses caused by contraction and expansion, and not to what is ordinarily supposed to be wear and tear. From my experience I find that grout composed of one part Portland cement and three parts fine sand makes a very desirable filler for brick pavements, and one which I have been recommending for alley paving, and expect to include in the street paving specifications."

The practice to-day, as gathered from the specifications of leading cities, is to fill the joints in brick pavements with cement grout composed of equal parts of cement and sand, although Columbus, Ohio, has specifications for a coal-tar pitch and asphalt filler. The specifications proposed by both the Organization for Standardizing Paving Specifications and the American Society of Municipal Improvements

Mr. Tillson. recommend Portland cement grout, but give requirements for coal-tar pitch and asphalt.

It also seems to be the general practice to have at the curb an expansion joint ranging from 1 to 1½ in. in thickness, filled with asphalt or some other bituminous filler.

Asphalt Block Pavements.—The filling of joints in asphalt block pavements seems to be done almost invariably with sand, the blocks being of such hardness that, under traffic, they practically weld together in warm weather, and do not require a filler except to hold them in a stable position until such action takes place. Sometimes, in repairing old pavements, when the old blocks are relaid, an asphalt filler is used, as it seems to revivify the asphalt in the blocks, making the edges stronger and better able to resist the traffic. This, however, makes the pavement a little more slippery than a sand filler, and when the blocks are laid on a grade, to avoid slipperiness, the bituminous joint would not be desirable. On practically level streets, however, it has generally proved satisfactory.

In the foregoing notes the speaker has attempted to show the general practice at the present time as regards the filling of joints of block pavements of all kinds, with the reasons for using the fillers, and his opinion as to the best. In summarizing, therefore, he would say that:

As regards stone pavements, sand, tar and gravel, and cement grout are being used, the latter much more extensively than either of the others, especially where an improved form of pavement is desired. His opinion is that where a stone pavement is not laid on a heavy grade, and where the elimination of noise is not an important element, the cement joint will be the most satisfactory, provided the street can be kept closed long enough to allow the grout to set thoroughly. Where the elimination of noise is important, he would prefer the joint described in referring to the Fourth Avenue pavement in the Borough of Manhattan.

For wood block, he is thoroughly in favor of a sand joint, as he believes that with it the wood pavement will be water-proof, even under a moderate traffic, that it will provide for the expansion of the blocks to a certain extent, and is the cheapest material that can be used.

For brick pavement, he believes, without qualification, that a Portland cement grout filler, with an expansion joint along the curb filled with bituminous material, is the best.

For asphalt block pavement, he believes in the sand filler, as already described, for a new pavement, occasionally using asphaltic cement in repairing old pavements.

Mr. Oxholm. THEODOR S. OXHOLM, M. AM. SOC. C. E. (by letter).—The writer has had charge of laying a considerable yardage of vitrified brick pavement in the Borough of Richmond, City of New York, during the

past ten years. A bituminous filler was used on much of this work. At first, it was composed of ordinary No. 4 coal-tar, but later a filler made from asphalt was used. The tar, while it adhered well to the bricks in summer, was apt to crack, powder, and blow away in winter. The asphaltic cement filler had a leathery appearance and failed to adhere properly to the bricks, there being only a few months in midsummer when a satisfactory piece of work could be had. In addition to this, it was noted that the filler wore away much faster than the bricks, thereby permitting the edges of the brick to spawl, thus materially increasing the roughness of the pavement in a few years. Mr. Oxholm.

While a pavement of this class is undoubtedly much less noisy in the first year or two than one in which the filler is cement grout, it is well settled that the increase in noise makes the pavement eventually more objectionable from this cause than one where the joints are filled with cement grout. The latter, in the writer's experience, has given a far superior piece of work, and the hollow sound sometimes noticed, due principally to lack of proper expansion joints along the curb, is less objectionable than the rumble of partly worn pavement with the asphalt cement filler.

Where traffic on a cement grout filled street is such that repairs to plumbers' cuts, etc., cannot be properly guarded for from 7 to 10 days, it would seem advisable to make repairs with tar or asphalt fillers.

BITUMINOUS SURFACES.

A. W. Dean, M. Am. Soc. C. E.—In introducing this topic, in order that there may be no misunderstanding of the scope of the subject, it should be stated that the generally accepted definition of a bituminous surface is "a surface consisting of a superficial coat or coats of bituminous material, with or without the addition of stone, slag, gravel, sand, or other similar material," thus distinguishing bituminous surfaces from bituminous pavements, the latter consisting of bituminous material and stone, slag, gravel, sand, or other similar materials incorporated together. Mr. Dean.

Bituminous pavements of various types have been in use for many years, whereas bituminous surfaces are of recent adoption. The early superficial applications of oil were made largely for the purpose of dust prevention on dirt roads, a crude light oil being used, having very little binding quality. The advent of motor-vehicle traffic, however, has led to a very extensive use of bituminous surfaces, not only for the purpose of dust laying, but for the preservation of the roads. As a natural consequence, many experiments have been tried by road authorities to determine what methods and materials are best adapted to overcome the difficulties encountered, and by producers to determine what quality of bituminous material can

Mr. Dean. be manufactured at a minimum cost to meet the requirements of the road authorities. Being still in the experimental stage, final conclusions regarding methods and materials are obviously impossible. It has been clearly demonstrated, however, that no uniform specification can be adopted defining a material which will produce a good bituminous surface on roads of every type and under every condition of traffic. Experience has shown, for instance, that while a heavy refined tar may be used to advantage on a macadam road, it is of no value as a surface application on an ordinary gravel or dirt road.

For surface treatment of dirt roads, a light oil helps somewhat to preserve the road, in that it prevents the particles composing the surface from blowing away, and assists, to some slight degree, in hardening the surface.

For surface treatment of gravel roads, the best results appear to be obtained by using an asphaltic oil of what might be termed medium viscosity, or by approximating the maximum viscosity that will permit application through an ordinary distributor at a temperature of 50° Fahr.

For surface treatment of broken stone roads, a light or medium oil acts mainly as a dust layer, yet if frequently applied it preserves the road to a very appreciable extent. In determining what bituminous material would be the most economical and advantageous for the preservation by surface treatment of broken stone roads, a knowledge of the traffic over the road is absolutely essential. If the road is subjected to light motor-vehicle traffic and light team traffic, with the motor vehicles predominating, experience has shown that an asphaltic oil, of such viscosity that it requires heating to at least 250° Fahr. before application, forms a bituminous surface which withstands the traffic and thoroughly preserves the road for a period of time depending partly on the quality of the material and workmanship and partly on the quantity of traffic.

Chemists do not agree unanimously on definite requirements for bituminous materials to be used for surface applications, and, as this method of treatment of roads is of such recent practice, it is probable that at least two years more must elapse before positive specifications can be drawn. Producers claim that the best oils for the purpose contain 90% asphalt. Although erroneous, it has become quite common to define asphalt oils in this manner, that is to say, by mentioning the alleged percentage of asphalt. When one considers the extreme heat which is applied to residuum oils in the process of manufacture, it is natural to form an immediate conclusion that the material may have become burned to a certain extent, and, consequently, be of quality inferior to oils derived by the use of natural asphalts. This may be true, but it must be proven in actual work before it can be accepted. Residuum oils placed on roads in Massa-

chusetts early in the season of 1909, still show life, and an indication of durability for a considerable time to come, and this fact would show that, while natural asphalts may possibly be superior, the residuum asphalts are, nevertheless, suitable for the purpose. Mr. Dean.

Fully as important as the quality of the bituminous material is the quality of the workmanship in applying it. In the preparation of the broken stone surface, extreme care should be taken to sweep and remove every particle of dust and dirt, so that the stones will be absolutely bare. Many failures of bituminous surfaces can be traced directly to the improper preparation of the broken stone surface, the heavy oils being distributed on dusty and dirty sections, and, consequently, peeling up through lack of adhesion. In order to get the best adhesion of asphaltic oils, it appears that the stone surface should also be somewhat moist rather than extremely dry. In distributing the oil, if the stone surface is comparatively new and smooth, the best results appear to be obtained by applying the oil under pressure in two applications, each of ¼ gal. per sq. yd., covering the first application with grit or pea stone before putting on the second, and covering the second application with the same material as soon as possible after it has been made. The effect of applying the material in this manner is to make the distribution more uniform and prevent surplus oil from flowing on the sloping crown of the road, thereby causing ridges and bunches to appear after the work has been done. If the stone surface is full of slight depressions, however, a single application of ½ gal. per sq. yd., applied with or without pressure, has proved satisfactory. The oil tends to run to the depressions, causing a slight surplus of oil in them, so that when the grit is applied on top of the oil, the portions over the depressions absorb more grit, consequently rendering the road more smooth.

The character of the grit or other material used for covering the oil is of great importance. Where the traffic is confined exclusively to motor vehicles, sand appears to be as effective as any material for covering, but if there is some steel-tired horse-drawn traffic, a coarse material like pea stone or fine gravel is necessary.

The cost of a bituminous surface as just described will vary, of course, with the availability of the material to be used for covering, and the length of haul of all materials. In Massachusetts, during the last four years, several hundred miles of macadam roads have been improved or preserved by a bituminous surface of this kind. The average cost during 1910 was a little less than $0.08 per sq. yd., and, during 1911, a little more than that price, with labor costing from $1.75 to $2.00 per 8-hour day, and asphaltic oil costing $0.06 per gal. delivered in tank cars. The detailed cost on an average road is as follows:

Mr. Dean.

	Per square yard.
Cleaning and sweeping	$0.0056
Patching old surface	0.0016
Cost of oil	0.0319
Heating oil	0.0031
Delivering oil	0.0038
Distributing oil	0.0029
Furnishing sand beside road	0.0165
Spreading sand	0.0073
Watering	0.0012
Rolling	0.0002
Supervision	0.0025
Total	$0.0766

The road mentioned was treated with ½ gal. of heavy asphaltic oil in two ¼-gal. applications. The average haul was 2 miles for the oil and 2½ miles for the sand. No allowance is made in the foregoing detailed statement for rental or depreciation of machinery, or for profits to contractor, the work being done by labor force account.

In maintaining these bituminous surfaces a re-treatment of about ¼ gal. of bituminous material per sq. yd. is only made on those places from which the bituminous material has disappeared. To show the probabilities of the cost of maintenance of roads by applying bituminous surfaces thereon, the speaker might cite 18 miles of State highway constructed in 9 towns in Massachusetts in 1909, the bituminous surface consisting of ½ gal. of residuum asphaltic oil. The first cost of the bituminous surfaces on these roads, in 1909, averaged $0.0742 per sq. yd. In 1910, there was expended for patching and sanding, $0.0146, and, in 1911, $0.0088 per sq. yd. The present condition of these roads indicates that the expense for patching and sanding in 1912 will not exceed $0.01 per sq. yd., in which case the total expense of maintenance of the surfaces on these roads for four years will have been $0.1076, making the cost $0.0269 per sq. yd., or approximately $236.72 per mile per year for a 15-ft. road, which cost does not exceed that of maintaining similarly located macadam roads previous to the advent of motor vehicles. Whether or not a bituminous surface, such as that just described, on a macadam road, will withstand the traffic of heavily loaded motor trucks cannot now be determined, as motor trucks have not been in use on such surfaces for a sufficient length of time and in sufficient numbers to permit such determination.

On roads where the prevailing traffic consists of steel-tired horse-drawn vehicles, this application of bituminous surface, consisting of heavy asphaltic oil and grit, has proved unsuccessful, in most in-

stances, the surface being cut and dented to such a degree that it soon disappears. On such a road, it is possible that a heavy, refined tar surface may be economical, or it may be economical to use oil of a lighter grade, applying it with sufficient frequency to keep the surface of the stone covered with oil at all times. The results, in the surface treatment of such roads in Massachusetts, would indicate that bituminous surfaces are not economical where the prevailing traffic consists of horse-drawn vehicles, but that a more durable construction of the crust of the road must be made by either mixing or penetrating the upper course of stone with bituminous material. Mr. Dean.

W. D. UHLER, M. AM. SOC. C. E. (by letter).—Under the writer's direction during 1911, more than 100 miles of water-bound macadam and gravel in the State Roads of Maryland, were treated with a dozen varieties of asphalt oils and tars. Detailed information as to materials and quantities used, cost, etc., is submitted in Table 1. Mr. Uhler.

As will be noted, the cost of these surface applications varied from 1.8 cents to 8.93 cents per sq. yd., or from \$148 to \$734 per mile; the cost of bituminous material varied from 3.75 cents to 9.1 cents per gal., f. o. b. at the point of delivery; grit for the top dressing cost from 0.33 cent to 3.5 cents per sq. yd. in place, depending on its character and location. With the exception of 16 miles on which the bituminous material was applied under pressure, it was all applied with gravity oilers. While varying conditions will affect the figures slightly, a fair average of the detailed costs is as follows:

	Per square yard.
Sweeping	\$0.0015
Pitch (delivered)	0.0300
Applying pitch	0.0045
Grit (delivered)	0.0030
Applying grit	0.0010
Total	\$0.04

In view of this experience, the writer has arrived at the following conclusions:

(1) The road to be treated must be thoroughly swept before applying the bituminous material; otherwise the results will not be satisfactory.

(2) On a newly finished macadam road, about ½ gal. per sq. yd. will be necessary.

(3) In applying ½ gal. per sq. yd., it should be applied in two treatments of ¼ gal. each, wherever practicable.

(4) After applying the bituminous material, sufficient time (from 12 to 24 hours) should be allowed, when possible, for it to penetrate,

Mr. Uhler.

TABLE 1.—COSTS OF ROAD SURFACES TREATED WITH BITU-
COMMISSION, MARYLAND,

County.	Name of road.	Con. No.	Length, in miles.	Width, in feet.
Allegany	Eckbart Mines-Garrett Co. L.	0140	2.86	14
	Std. Oil Warehouse Section	0142	1.25	12, 14 and 16
Caroline	Denton-Federalsburg	051	0.68	14
	Denton-Federalsburg	053	3.63	14
	Denton-Federalsburg	053	0.40	14
	Denton-Federalsburg	054	2.68	14
	Greensboro-Denton	055	4.07	14
Carroll	Sykesville-Eldersburg,	0200	2.59	12 to 14
	Nicodemus	0206	1.00	12 to 14
Cecil	Conowingo-Porter's Bridge	040	1.06	14
	Conowingo-Porter's Bridge	040	2.06	14
	Rising Sun-Calvert	041	1.04	14
	Rising Sun-Calvert	041	2.22	14
	Elkton-Singerly	043	2.35	14
Charles	La Plata-White Plains	0150	4.63	14
Dorchester	Shiloh Church-East New Mkt	071	2.61	14
	Shiloh Church East New Mkt	071	0.138	14
	E. New Market-Mt. Holly	072	1.80	14
	E. New Market-Mt. Holly	072	4.10	14
Frederick	Jefferson Pike	0245	3.00	12
Garrett	Oakland-Thayerville	0161	5.61	14
Harford	St. Ignatius Ch.-Graf. Shops	0171	1.12	12 to 14
	Belair-Kalmia	0175	0.51	14
Howard	Baltimore-Washington, Sec. 3	01	1.18	12
Kent	Chestertown-Kennedyville	0120	3.28	14
Montgomery	Rockville-Gaithersburg	0230	2.01	12 to 14
Pr. George	Forestville-Marlboro	0130	2.07	14
	Dist. Col.-Charles Co. Line	0131	2.74	14
	Dist. Col.-Charles Co. Line	0131	1.28	14
	Dist. Col.-Charles Co. Line	0131	1.79	14
	Marlboro Road, Section 1	0138	1.31	12
Queen Anne	Centreville-Church Hill	0101	3.05	14
	Centreville-Church Hill	0102	3.14	14
St. Mary's	Mechanicsville-Leonardtown	020	5.34	14
	Mechanicsville-Leonardtown	021	3.49	14
Talbot	Easton-Wye Mills	0111	4.94	14
	Salisbury-Mardella Springs	080	1.80	14
	Salisbury-Mardella Springs	080	1.80	14
	Salisbury-Mardella Springs	080	1.29	14
	Salisbury-Mardella Springs	080	2.37	14
Worcester	Berlin-Snow Hill	060	4.56	12
	Berlin-Snow Hill	060	3.41	12
			102.258	

(1) Passing ¾ in. and retained on No. 8 screen.
(2) Sand medium size.
(3) Washed gravel; average ⅜ in.
(4) Granolithic passing ⅜ in. and retained on No. 10 screen.

and the road should then be covered with a light application of coarse sand, pea gravel, or granolithic chips. About 40 tons to the mile (14 ft. wide) have been found to be sufficient in most cases.

(5) In view of the experience with gravity and pressure distributors as to results, time, etc., it is thought advisable, as well as economical, to use a motor truck, fitted so as to apply the bituminous material under pressure.

MINOUS MATERIAL, MAINTENANCE DIVISION, STATE ROADS JAN. 1ST, TO DEC. 31ST, 1911. Mr. Uhler.

Trade name of bituminous material used.	Date of treatment.	Total cost.	Total cost per square yard.	Gallons per square yard.	Pounds of grit per square yard.	Character of top dressing used.
Fairfield No. 2	8/26– 9/20	$1 177.42	$0.0500	0.481	4.66	Limestone and sandstone chips (1).
Trinidad "A"	9/22–10/11	734.18	0.0694	0.660	17.06	
Asphaltoilene	6/ 2– 6/ 9	282.59	0.0504	0.500	......	No top dressing.
Ugite	5/22– 5/26	1 027.67	0.0344	0.427	7.84	Local sand (2).
Asphaltoilene	6/10– 6/13	171.31	0.0520	0.50	......	No top dressing.
Trinidad "A"	8/16– 9/ 4	899.74	0.0409	0.526	9.63	Local sand (2).
Ugite	6/ 5– 6/28	1 082.03	0.0324	0.410	6.73	Local sand (2).
Ugite	7/17– 8/12	1 023.49	0.0507	0.548	7.33	Pea gravel (3)
Trinidad "A"	7/28– 8/ 4	407.59	0.0525	0.570	7.50	Local sand (2).
Standard No. 5	6/ 7– 6/19	412.37	0.0473	0.526	11.32	Stone chips (4).
Tarvia "B"	6/ 7– 6/26	668.73	0.0395	0.474	......	No top dressing.
Standard	5/23– 5/30	305.29	0.0358	0.526	10.02	Chips (4).
Ugite	6/ 1– 6/ 6	788.38	0.0431	0.481	10.08	Chips (4).
Texas 60%	6/24– 7/ 3	880.86	0.0455	0.509	5.87	Local sand (5).
Ugite	7/26– 8/ 9	1 650.29	0.0434	0.600	9.07	Local gravel (6).
Texas 60%	7/20– 9/ 4	1 010.92	0.0471	0.533	6.00	Local sand (2).
Trinidad "A"	9/2	48.67	0.0427	0.438	6.00	Local sand (2).
Texas 60%	7/ 2– 8/10	646.63	0.0437	0.520	6.83	Local sand (2).
Trinidad "A"	7/22– 9/10	1 453.08	0.0431	0.553	5.80	Local sand (2).
Gulf-Asphalt "C"	8/ 1– 8/10	380.73	0.0180	0.380	......	No top dressing.
Asphaltoilene	6/24– 8/ 1	2 720.35	0.0591	0.500	......	No top dressing.
Texaco Special	9/29–10/31	550.40	0.0687	0.520	7.94	⅜-in. gravel (3).
Texaco Special	9/29–10/31	336.83	0.0801	0.498	8.33	⅜-in. gravel (3).
Standard No. 5	6/27– 6/28	240.70	0.0247	0.400	......	No top dressing.
Texas 60%	8/30– 9/21	1 076.80	0.0399	0.480	6.96	Local sand (5).
Trinidad "B"	10/12–11/ 7	1 367.78	0.0893	0.498	36.03	⅜-in. gravel (3).
Ugite	6/ 5– 6/24	747.64	0.0440	0.510	9.97	Local gravel (6).
Trinidad "A"	9/22–12/ 8	1 414.78	0.0627	0.490	13.20	Local gravel (6).
Ind. Refg. Co. Liq. Asph.	9/22–12/ 8	995.70	0.0948	0.707	30.43	Local gravel (6).
Fairfield No. 2	9/22–12/ 8	891.41	0.0606	0.442	12.40	Local gravel (6).
Trinidad "A"	8/14– 8/25	482.18	0.0522	0.544	11.50	Local gravel (6).
Ugite	8/14– 9/ 8	1 185.74	0.0472	0.518	9.93	Chips (4).
Ugite	9/27–10/14	1 092.40	0.0423	0.540	3.49	Chips (4).
Standard No. 5	6/30– 7/14	1 010.08	0.0270	0.333	3.68	Local sand (7).
Standard No. 5	7/ 3– 7/20	667.13	0.0272	0.333	4.15	Local sand (7).
Fairfield No. 2	9/ 5– 9/26	1 498.13	0.0369	0.515	......	No top dressing.
Trinidad "A"	6/13– 7/ 5	692.11	0.0468	0.54	9.00	Local sand (7).
Standard No. 5	6/13– 7/20	489.67	0.0331	0.54	9.00	Local sand (7).
Texas 60%	6/13– 7/20	652.33	0.0617	0.726	9.00	Local sand (7).
Fairfield No. 2	6/13– 7/20	655.23	0.0337	0.41	9.00	Local sand (7).
Asphaltoilene	10/ 7–10/28	1 737.75	0.0541	0.492	......	Sand from sides (7)
Ugite	10/ 9–10/28	969.20	0.0403	0.500	......	No top dressing.
		$36 526.30				

(5) Coarse sand.
(6) Unscreened gravel.
(7) Fine sand.

ARTHUR H. BLANCHARD, M. AM. SOC. C. E.—During 1911 American manufacturers met the demand for low-priced distributing machines by placing on the market more than fifteen kinds, including both the pressure and gravity types. All these machines are more or less suitable for distributing one or more of the various kinds of materials used for the construction and maintenance of bituminous surfaces. They have not been calibrated for all materials, however, so that if Mr. Blanchard.

Mr. Blanchard. the physical properties of the material, the temperature at which it is to be used, and the speed at which the machine travels, are known, the quantity they will apply per square yard can be definitely predicted. The speaker has found it advisable, therefore, before purchasing a machine, to secure reliable data covering the limitations relative to the character and quantity of material which it is capable of distributing, and the method and cost of operation.

There are, however, some well-known general limitations; for instance, it has been found extremely difficult with a gravity machine to distribute uniformly less than 0.4 gal. per sq. yd. with certain grades of material, unless the material is brushed into the road, with brushes attached to the machine or in the hands of workmen. With some of the pressure machines, however, it is possible to obtain a uniform application with certain kinds of materials in quantities as small as 0.1 gal. per sq. yd. On the other hand, it has been found uneconomical to apply, with any of the 1911 pressure distributors, certain grades of asphalt suitable for the construction of bituminous macadam pavements or for the application of some asphalts, solid at air temperature, used for seal coats on bituminous concrete pavements.

The hand-drawn gravity distributor will probably prove more economical and efficacious for the application of seal coats on bituminous concrete pavements than any other type of distributor. Since the seal coat is applied to the wearing surface as soon as a stretch of the latter is ready to receive it, the amount of work to be done in any one day is small, and would not usually warrant the use of a distributor of large capacity.

During the season of 1911 the speaker has noted a growing objection to the use of materials, for the construction of bituminous surfaces, which require from 2 to 6 weeks to set up to such an extent that tracking will not occur. By "set up" is meant that condition of the surface under which there is practically no tracking of the bituminous material or surface coat. During 1911 the speaker used several materials which have given satisfactory results from this standpoint. These include certain refined coal-tars and water-gas tars, combinations of asphaltic materials and refined tars, and an asphalt made of Gilsonite and asphaltic oil. It is reported that in Maryland certain cut-back Texas asphalts have given similar results. The following is an analysis of the Gilsonite asphalt compound, made in accordance with the methods proposed by this Society's "Special Committee on Bituminous Materials for Road Construction":

Specific gravity	0.98
Melting point of normal material, in degrees, centigrade	58
Solubility in carbon disulphide, percentage	99.7

Mr. Blanchard.

Ash, percentage	0.1
Solubility in 88° Baumé paraffin naphtha, percentage	75.5
Fixed carbon, percentage	7.8
Viscosity, N. Y. T. L. viscosimeter, in inches	51
Penetration of normal material:	
No. 2 needle, 100g., 25° cent., 5 sec	136
No. 2 needle, 200g., 0° cent., 1 min	55
Evaporation 5 hours at 170° cent., percentage	0.5
Melting point residue, in degrees, centigrade	62
Penetration of residue:	
No. 2 needle, 100g., 4° cent., 5 sec	30
No. 2 needle, 100g., 25° cent., 5 sec	102
Evaporation, 5 hours at 205° cent., percentage	3.4
Melting point residue, in degrees, centigrade	75
Penetration of residue:	
No. 2 needle, 100g., 4° cent., 5 sec	19
No. 2 needle, 100g., 25° cent., 5 sec	75

The speaker has found that, within 24 or 48 hours, bituminous surfaces constructed with the above materials, using ½ gal. per sq. yd. and a thin covering of sand or chips, have set up so that no tracking is noticeable. Tar and tar asphalt compounds have long been recognized as having this property, but asphalts and asphaltic oils suitable for bituminous surfaces, from the above standpoint, have been difficult to procure.

Mr. Connell.

WILLIAM H. CONNELL, ASSOC. M. AM. SOC. C. E. (by letter).—The experience of 1910 in the Borough of the Bronx having proved that bituminous surface applications were more efficacious and economical than water sprinkling on macadam and earth roads, the water sprinkling division has been abolished, and all the macadam and a number of earth roads have received a surface treatment of tar or asphalt road oil. The results from tar have been very satisfactory, about ⅓ or ½ gal. per sq. yd. being applied and covered with torpedo sand or fine wash gravel. This formed a very desirable surface, at a cost of $0.035 for ⅓ gal. and $0.045 for ½ gal. per sq. yd. In these treatments the tar was applied cold.

The Grand Boulevard and Concourse was treated with a heavier tar, which was applied under pressure through a hose at a temperature of 220° Fahr., ⅜ gal. per sq. yd. being used, and then covered with torpedo sand or fine wash gravel. This road has been in use for 6 months, and although it has been subjected to very heavy, high-speed, automobile traffic, it is now in first-class condition. The cost was $0.138 per sq. yd., which is high, owing to the lack of proper facilities for

Mr. Connell. handling the bituminous material and the numerous delays which occurred. In the Borough of the Bronx a fair cost would be from \$0.09 to \$0.10 per sq. yd. for this treatment. Before the application of tar in these treatments, the road was thoroughly swept with horse-drawn and hand brooms.

Asphalt road oil of about 20° Baumé gravity was applied to a number of macadam roads, using $\frac{1}{4}$ gal. per sq. yd. On roadways having light or medium traffic, one application a year was sufficient to keep the road dustless; heavily traveled roadways required two and, in some instances, three applications. The cost of this treatment was \$0.013 per sq. yd. when $\frac{1}{4}$ gal. per sq. yd. was used. The oil was applied with a pressure distributor on a number of roadways, and the cost was \$0.009 for $\frac{1}{5}$ gal. per sq. yd. This method of treatment is both economical and desirable. Just enough pressure was applied (about 15 lb.) to drive the oil into the interstices of the stone to a sufficient depth to avoid having a mushy road surface. Before the application of the asphalt road oil, the surface was swept with a horse-drawn sweeper only.

Preparations are now under way to equip the Bituminous Application Division with a sufficient number of pressure distributors to do all the bituminous surface work in 1912. For the cold treatments, the distributing device can be attached to an ordinary water sprinkler. The heavier materials will require the use of heater wagons. Considerable stress has been laid on this method of application, because, in the writer's opinion, it results in saving not only labor, but also bituminous material, as the latter is applied to the road in such a manner that there is little chance of it being washed away.

The bituminous material applied to the different roadways was selected from the standpoint of its adaptability for each particular case. The stone used consists largely of Rockland Lake and Clinton Point crushed trap rock.

The following table gives a comparison of the cost of surface treatments and water sprinkling in the Borough of the Bronx, the water sprinkling being based on sprinkling from three to four times a day for 180 days, at \$5 per day for a team, and water at \$0.10 per 100 cu. ft.

Tar, $\frac{1}{3}$ gal. per sq. yd.	\$0.035
" $\frac{1}{2}$ " " " "	0.045
Asphalt road oil, about 20° Baumé gravity, $\frac{1}{4}$ gal. per sq. yd.	0.013
Two applications	0.026
Asphalt road oil, about 20° Baumé gravity, pressure distributor, $\frac{2}{10}$ gal. per sq. yd.	0.009
Two applications	0.018
Water sprinkling	0.051

In order to compare these costs with those of other localities, the following figures relating to materials and wages paid to laborers and foremen in the Borough of the Bronx, are submitted: Mr. Connell.

Foremen	\$4.00 per day.
Laborers	2.25 " "
Average price of tar at freight yard	0.061 per gal.
Average price of asphalt road oil at freight yard	0.04 " "
Torpedo sand, on the work, but not spread	1.30 per cu. yd.

With the use of pressure distributors in 1912, the cost of applying the tar will be greatly reduced. The present method requires the services of three laborers, whereas a distributor will need only one man to operate it, and moreover, the time required to apply the tar will be reduced to a minimum.

USE OF BITUMINOUS MATERIAL IN PENETRATION AND MIXING METHODS.

LINN WHITE, ESQ.* (by letter).—In offering this contribution on the use of bituminous materials in road construction, it is believed that safe conclusions can be drawn in such matters only from experience and direct observation. Therefore, what is offered will relate to work in Chicago and vicinity, particularly to the road work in the South Park System of that city. Mr. White.

The South Park Commissioners have under their control about 60 miles of drives, including various boulevards and park drives, all lying within the southern division of the city. The traffic over these drives varies from a maximum of 17 000 vehicles per 24 hours, of which 4 000 are heavily-loaded traffic teams, which extreme condition occurs on the northern end of Michigan Avenue, down to a minimum of a few hundred vehicles on the more remote boulevards, which carry no through traffic. The comparatively few miles of boulevard in the down-town district carrying the heavy down-town traffic, such as the northern end of Michigan Avenue, alluded to above, and Jackson Street, have long been paved in a substantial way, and will not be referred to further. Of the 60 miles of drives in the system, 90% is paved either with plain water-bound macadam or a bituminous wearing surface supported on macadam. The water-bound macadam surfaces are being maintained in a usable condition with as little cost as practicable until such time as they can be given a bituminous wearing surface. The through traffic on the principal park drives and various boulevards through the residential district, at an average distance of 6 or 7 miles from the center of the city, amounts to from 3 000 to 5 000 vehicles per 24 hours, in average fair weather, but

* Chief Engineer South Park Commission, Chicago, Ill.

Mr. White. this may be greatly decreased during bad weather conditions or greatly increased on Sundays and holidays during fine weather. As traffic teams are excluded, at least 75% of the vehicles are automobiles, but, on the numerous intersecting streets, the general traffic moves unrestricted across the boulevards, and must be added to the foregoing figures and reckoned with in considering the effects of traffic on the pavement surfaces. These brief statements should serve to give a general understanding of the conditions under consideration.

In 1905 bituminous treatment for preserving the macadam surfaces was begun, in an experimental way at first, but, under the comparatively dense traffic conditions, experience was rapidly gained. The emulsions and light road oils which were tried were quickly abandoned because of constant complaint from residents about the resulting sloppy, disagreeable conditions of the drives, as well as the failure of these materials to add much, if any, bonding value to the surface. Most of the macadam was of limestone, of none too hard a quality, which wore and disintegrated rapidly under the increasing traffic, and required something of more positive cementing value than could be obtained from the lighter forms of bituminous material. The first apparent success was with Tarvia of the grade afterward sold as "A." In the first experiments the tar was applied to the completed and well-filled surfaces of the macadam and covered with a top dressing of limestone screenings, thus securing a well-defined cushion coat and such penetration as good luck might bring.

In 1906 and 1907, 290 000 sq. yd. in the South Park System were surfaced in this manner, at an average cost of 5.7 cents per sq. yd. for the bituminous surface alone, and 19.5 cents per sq. yd. including the necessary re-dressing of the macadam and the addition, in some cases, of variable quantities of new stone. The quantity of bituminous material used was from $\frac{1}{3}$ to $\frac{1}{2}$ gal. per sq. yd. The results were variable and not always encouraging. When the macadam was somewhat dirty, or had an excess of fine material in its composition, the penetration was indifferent, and the surface scaled off, sometimes within a few weeks. The first improvement was to use clean limestone chips for the top dressing, and the next was to finish up the macadam so that there would be plenty of surface voids to secure penetration. In 1907, the necessity and means of securing penetration were beginning to be understood, and the work of this year was much more successful than that of 1906.

The first section of work done in Chicago, following what are now recognized as correct penetration methods, was in August, 1907, on Michigan Avenue from 41st to 42d Streets. Here was used a specially prepared grade of Tarvia, of about 1.20 gravity at 60° Fahr., corresponding to what was soon afterward put on the market as Tarvia "X." The quantity used was $1\frac{3}{4}$ gal. per sq. yd., and the cost was

approximately 31 cents per sq. yd., including 1½ in. of new stone. This produced a fairly substantial surface, but it was torn up in 1909 on account of carrying through a uniform improvement. It was not worn out after 2 years of service, but had developed some disintegrated spots, and had the fault of bleeding under the hot summer sun, leaving it sticky when hot and glassy when cold. If provision had been made for a somewhat deeper penetration, or if more fine material had been rolled in when first constructed, so that there would not have been as much bituminous material near the surface, this condition might have been improved. Mr. White.

Other materials than Tarvia were used for penetration work, principally oils with heavy asphaltic contents requiring about 200° of heat for application. One section of Grand Boulevard surfaced in this way with California maltha of 1 gal. per sq. yd., at a cost of 23 cents per sq. yd., without the use of any new stone except the top dressing of stone chips, waved and rutted so badly under traffic as to be at times almost impassable. Repeated rolling, with a liberal application of screenings, failed to cure the defect, and the road was torn up in 1909. An analysis of the trouble indicates that it was due to insufficient penetration in the old and dirty macadam, and to the presence of too much fine mineral matter. On a layer of clean coarse stone the results would undoubtedly have been more satisfactory.

In 1908, about 200 000 sq. yd. of penetration work were laid, 10 000 sq. yd. being laid by the mixing method, following some previous small experiments. Some of the penetration work of 1907 was given a second coat of Tarvia of about ½ gal. per sq. yd., which had the effect of adding a cushion coat without securing any penetration except where the surface was disintegrated. A second and even a third coat may be added with success, if there is a substantial structure of sound stone beneath; otherwise a shifting, unreliable surface will be obtained. Of the penetration work done in 1907 and 1908, amounting to 350 000 sq. yd., there remains in use about 100 000 sq. yd., of which 34 000 sq. yd. will have to be replaced with a new surface in 1912. None of the 1905 and 1906 work remains, and none of the 1907 and 1908 penetration work on street intersections, where miscellaneous traffic crosses the boulevards. All the 100 000 sq. yd. mentioned as being still in service, is where traffic is restricted and is principally rubber-tired.

As previously stated, in 1908 the first surfacing was done by the mixing method, amounting to about 10 000 sq. yd. No satisfactory machinery seemed to be available for mixing, unless standard asphalt paving plants were considered, and hand-mixing was recognized as being too expensive and slow. At the beginning of the season of 1909, there was on the market a portable plant manufactured by the Link Belt Company, of Chicago, which embodied all the essential parts of

Mr. White. an asphalt paving plant mounted on one truck. The South Park Commissioners purchased two of these plants, which have been kept in use during the seasons of 1909-10-11, and, up to date, about 435 000 sq. yd. of mixed bituminous wearing surface have been laid with them, principally on the old macadam. A comparatively small amount has been laid on a new macadam base, but the method of construction was the same. The methods of doing the work have progressed from experiment to experience, and from experience to what may be considered established practice, in a process of evolution somewhat similar to that previously described for the pouring and penetration methods. More attention is now given to preparing the base with a coarse, open, and grainy top, into which the surfacing mixture may be forced. In the earlier work the macadam surface was left comparatively smooth, and dependence was placed on the composition of the mixture and the stability of the binder to prevent the shifting of the surface.

The bituminous wearing course in most of the work has been made 2 in. thick, in some 1½ in., and in a small quantity about 1 in. The later conclusions are that a comparatively thin and completely water-proof wearing surface, with a strong, coarse layer of stone keying it to the macadam base and giving lateral stability, is the most logical, economical, and successful construction, the layer of coarse stone corresponding somewhat to the binder course in sheet-asphalt pavements. The thickness of the wearing surface may be varied in the judgment of the engineer to meet the stress of traffic and amount of money available.

Careful records of cost have been kept and may be concisely stated as follows:

	Labor.	Materials and supplies.	Total.
2 in. thick...........	$0.16	$0.36	$0.52
1½ " "	0.14	0.28	0.42
1 " "	0.12	0.20	0.32

These figures do not include the preparation of the base, overhead charges, or interest and depreciation. The same is true of any other figures of cost mentioned by the writer. The cost of labor and supplies in Chicago probably does not vary materially from that in any other large city in the United States, and the costs given above are based on the following average prices of materials used in the wearing surface:

Road asphalt........................	$20.00 per ton.
Crushed limestone..................	1.65 " cu. yd.
Sand	1.50 " cu. yd.

The bituminous cements used have been asphaltic compounds, natural asphalts, and, to a limited extent, refined tar of from 1.20 to 1.29 gravity at 60° Fahr.

Mr. White.

All the surfacing done by the mixing method during the past 4 years, beginning with 1908, is giving good service with less than one-half of 1% of repairs up to date. Some weaknesses of construction have developed at certain points where the stress of traffic has been the greatest, and have caused the small amount of repairs referred to. On some of the earlier pieces of work, surface cracks or checks have appeared, but it is believed that the better methods of construction, particularly the use of the coarse, open-stone base, have to a large extent overcome this tendency. The two other Park Commissions in Chicago, the West Park Commission and the Lincoln Park Commission, have adopted the same methods for surfacing macadam, and are using the same machinery for mixing and preparing the material. Altogether, there has been laid in Chicago by the three Park Boards nearly 1 000 000 sq. yd. by the mixing method.

In its meetings of the last three years the organization of City Officials for Standardizing Paving Specifications has adopted specifications for work of this class, under the name of "Bituminous Concrete," based principally on Chicago practice.

In conclusion, it may be said that the additional cost of surfacing by the mixing method over first-class construction by the penetration method is so slight, and the advantages of uniform results and longer service attained are so considerable, that every municipality should look carefully into it before deciding on the inferior method. It is probably true that it should not supersede the penetration method in all cases, but where there is a growing traffic, urban, suburban, or interurban, it will be the better method of construction.

Mr. Richardson.

CLIFFORD RICHARDSON, M. AM. SOC. C. E.—It has been the speaker's experience that for the construction of bituminous macadam roads a hard limestone will prove extremely satisfactory. He has in mind two limestone roads constructed in New York which have shown certain characteristics, but which are preferable to those built of trap rock. This may be accounted for by the fact that a trap-rock fracture is a very glassy one. If any bituminous material should be poured on a sheet of glass, such as ordinary window glass, it could be torn away from that surface much more readily than if the surface was of ground glass. A limestone fracture, being somewhat granular in appearance, resembles ground glass more than trap rock, so that a better adhesion of the bituminous material results with limestone than with trap rock. Moreover, limestone under pressure produces a certain amount of detritus or dust, which acts as a better filler than the dust of trap rock. Good hard limestone has a better fracture than trap rock, especially Hudson River trap, which is another reason why the former is more desirable. As long ago as 1837, when Gillespie published his book on highways, he called attention to the fact that Hudson River trap rock is not as desirable as that in many other parts of the country.

Mr. Richardson.

The speaker has looked into the matter of stone-crusher products very carefully. Stone quarries are equipped with screens which cannot be changed to suit the convenience of engineers. The sizes of screens which have been suggested for future specifications are not just what will be found at the plants of the various quarries.

In constructing roads of gravel and sand the speaker has found it desirable, in a number of cases, to ascertain the voids in the gravel in order to know the exact quantity of sand necessary to fill them. In order to obtain a satisfactory compaction, about 5 or 10% more sand must be added than the voids in the gravel demand.

The great difficulty with the work of this type which has been done is that the pavements have a tendency to bleed, but if the voids in one lot of gravel are carefully calculated, and if the variations in the bank are not too great, the results will be successful. One of the experimental sections of the White Plains Road in the Borough of the Bronx was constructed in this manner, and shows the possibility of doing successful work.

It has been stated that bituminous work should not be carried on after September 30th, or when the air temperature is below 50° Fahr. This is a very wise precaution, although the speaker thinks that the temperature might be reduced to 40° and the fixed date omitted. For instance, during the summer of 1911, work could be satisfactorily done in October, whereas the year before, the weather conditions were such that no satisfactory work could be done at all in that month. Many of the defects of bituminous roads have been due to the fact that work is done in the fall, and an opportunity of at least a month during warm weather should be given to the contractor to finish up his work for the season, no matter whether the road is being built by penetration or mixing methods.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

BENJAMIN DOUGLAS, M. Am. Soc. C. E.*

DIED NOVEMBER 12TH, 1911.

Benjamin Douglas, son of Judge Samuel Townsend Douglas and Elizabeth (Campbell) Douglas, was born at Detroit, Mich., on December 10th, 1859. Most of his life was spent on Grosse Isle, a large island in the Detroit River, where his father had built a home in 1859.

His early education was given to him by his mother, who also prepared him for entrance into the University of Michigan. He was one of a small class in Civil Engineering in that University, and was graduated in 1882.

On leaving college Mr. Douglas became Assistant Engineer in the Detroit Bridge and Iron Works, where he remained until February, 1885. He then became Engineer of Bridges on the Michigan Central Railway, which position he retained for twenty years. Mr. Mock, of that Railway Company, says:

"The notably successful way in which he met the problems incident to the rebuilding of bridges with the least interruption to traffic, and the entire reliability of his work, gave him a high standing among the Bridge Engineers of the United States and Canada.

"He replaced the bridge over the Grand River, in 1891, by moving out the old bridge, one span at a time, and moving in the new span from its temporary support alongside, and, on the last two sections of 154 ft. each, accomplished the substitution, with the bridge ready for use, inside of 26 minutes. This was one of the first bridges, if not the first, to be so handled, and I think it is a record unbeaten to this day."

Mr. Douglas also had charge of the rebuilding and strengthening of the Cantilever Bridge at Niagara. In 1894 he designed the first bridge with a solid I-beam ballast floor, a construction which is far superior to any except concrete.

"To him is due, in a very large measure, the success attending the building of the Detroit River Tunnel, for which he represented the Michigan Central Railway. This tunnel is a new departure in subaqueous tunnel building, and its problems called forth a large number of designs—one such was made and patented by Mr. Douglas."

On the completion of the tunnel Mr. Douglas opened an office as Consulting Engineer, and, in that capacity, went to Southern Brazil, where he was engaged on the Soro Cabaña Railroad. This road was being reconstructed and extended, and presented many bridge and

* Memoir prepared by the Secretary from papers on file at the House of the Society and from information furnished by his family.

viaduct problems. His work there was almost completed, when, by a misstep on the temporary flooring of a high viaduct, he was precipitated to the ground below and almost instantly killed. Through the kind offices of his friends in Brazil, and of the officials of the Soro Cabaña Railroad, after a service by Bishop Kinsolving in the little church of Santa Maria, his remains were sent to New York, whence they were conveyed to his home to be interred beside his parents and grandparents in the old cemetery in Detroit.

Mr. Douglas' life was a peculiarly harmonious one. He found in his beautiful home and farm congenial occupation for all the time not given to his profession. His devotion to his parents was repeated in the affection of his own family life. A man of sterling integrity, his modesty and reserve concealed to some extent his abilities in his profession and the fine qualities which he possessed, but these were gradually understood and appreciated by those who came in contact with him or his work. He chose that which was best in life, and worked steadily toward it.

He was a Past-President of the Detroit Engineering Society; a member of the Michigan Engineering Society (and in November, 1911, was appointed on the Legislative Committee of that Society); a Member of the American Railway Engineering and Maintenance of Way Association, and a member of Tau Beta Pi, the honor society of graduate engineers in the University of Michigan.

Mr. Douglas was elected a Junior of the American Society of Civil Engineers on June 1st, 1887, and a Member on January 2d, 1890.

HENRY FIDDEMAN LOFLAND, M. Am. Soc. C. E.*

Died January 12th, 1912.

Henry Fiddeman Lofland was born in Milford, Del., on June 24th, 1862. He was graduated from the University of Virginia in 1883 with the degree of C. E., and immediately became connected with the Baltimore and Ohio Railroad as Assistant Engineer on the construction of the substructure of the Susquehanna River Bridge, near Havre de Grace, Md., on the line then being built between Baltimore and Philadelphia. The building of the substructure of this bridge was notable as being one of the most important operations in deep pneumatic foundation work that had been undertaken up to that time, and on its successful completion, Mr. Lofland served in the same capacity on the construction of the substructure of the Baltimore and Ohio Bridge over the Schuylkill River, in Philadelphia.

* Memoir prepared by S. P. Mitchell, M. Am. Soc. C. E.

In June, 1886, on the completion of the latter work, he was engaged as Engineer in charge of bridge substructures on the East Georgia and Florida Railroad, and in December of the same year became Division Engineer on the Mobile and Birmingham Railroad, having charge of building the substructure of the Tombigbee River Bridge. In July, 1887, he was made Division Engineer on the construction of the Louisville, St. Louis, and Texas Railroad, remaining in that position until February, 1888, when he took charge of the surveys for the Louisville and Jeffersonville Bridge over the Ohio River, near Louisville, Ky.

In April, 1888, Mr. Lofland returned to the Baltimore and Ohio Railroad as Assistant Engineer on construction, remaining in this position until April, 1891, when he accepted an appointment as Assistant Engineer of Erection with the Edge Moor Bridge Works, of Wilmington, Del. In 1897, he was promoted to the position of Engineer of Erection, which position he filled until the formation of the American Bridge Company, in 1900, when he was appointed Assistant Engineer of Erection of that Company.

Upon the formation of the American Bridge Company of New York, in 1901, he was made Division Erecting Manager, having charge of all the erection and outside construction work of this Company in the Eastern section of the United States, with headquarters at Philadelphia. He held this position until 1906, when he was promoted to General Manager of Erection, in general charge of all outside construction work, which position he held at the time of his death.

Mr. Lofland's engagement with the Edge Moor Bridge Works in 1891 proved to be the turning point in his career, for from that time his professional activity was directed exclusively to specializing in the erection of bridges and steel structures; however, the broad knowledge gained from his experience in general railroad construction and the building of substructures, was undoubtedly of the greatest value as a basis on which to found his life work. At the period mentioned, the present-day problems in bridge erection, due to the enormous increase in size and weight of structures, and particularly the problems encountered in the renewal of railway bridges under the most exacting traffic conditions, existed only to a limited degree; consequently, the organization, methods, and appliances in use were naturally crude, and this branch of bridge building was only beginning to be recognized as a specialty requiring the ingenuity and skill of educated engineers. It may be fairly said that no one has contributed more than Mr. Lofland to the marked advancement and development which has taken place in this art in the last twenty years, during which time he was connected with the erection of some of the largest bridges in the United States.

Mr. Lofland was the happy possessor of those qualities making

for success which are seldom found in one person—natural engineering talent, resourcefulness, force of character, and remarkable energy, combined with executive ability of a very high order and the faculty of handling men. He was, further, a man of sterling integrity in his business and personal relations, and commanded the respect and admiration of his friends and opponents as well.

In addition to his professional qualifications, there was another side to Mr. Lofland's character which stood out with equal prominence, namely, his social gifts. Possessed of a genial personality, engaging manner, and an inexhaustible fund of natural humor, which made him a delightful companion, he formed lasting friendships wherever he went. He was a raconteur of reputation, not only in the usual sense, but invented many of his own stories, and could turn the most commonplace incident into a humorous anecdote. With his love of social life and his great popularity with both sexes, it is rather remarkable that he never married.

Mr. Lofland's death was not only a severe blow to his friends, but a serious loss to the Engineering Profession. He had been in poor health for three years, but did not give up active work until July 15th, 1911, when he was granted a year's leave of absence, and returned to his old home in Milford, Del., where he died on January 12th, 1912. He is survived by one brother and three sisters.

Mr. Lofland was elected a Member of the American Society of Civil Engineers on June 2d, 1897.

FRANK OTIS MELCHER, M. Am. Soc. C. E.*

Died January 22d, 1912.

Frank Otis Melcher was born on June 14th, 1864, at Damariscotta, Me. He was graduated from Tufts College, Massachusetts, in 1887, with the degree of A. M. B. In 1896 he received the degree of Civil Engineer from that college.

After his graduation Mr. Melcher commenced work on the Fitchburg Railroad as Instrumentman, and, later, was appointed Assistant Engineer and then Chief Engineer of that road. In 1897 he was appointed Division Superintendent, and was promoted to General Superintendent during the following year. From July, 1900, to November 1st, 1902, he was Superintendent of the Fitchburg Division of the Boston and Maine Railroad, which had taken over the Fitchburg Railroad.

On the latter date Mr. Melcher became Superintendent of the Illinois Division of the Chicago, Rock Island and Pacific Railroad; in

* Memoir prepared by the Secretary from information supplied by J. B. Berry, M. Am. Soc. C. E., and from papers on file at the House of the Society.

February, 1904, he was made General Superintendent of the Choctaw District, and in June, 1905, General Manager of the Central and Northern Districts. In December, 1906, Mr. Melcher's jurisdiction as General Manager was extended over the entire system of the Chicago, Rock Island and Pacific Railroad, and on the dissolution of the Rock Island-Frisco System, in December, 1910, he was elected Second Vice-President, in charge of the Operating Department of the Rock Island road, succeeding Mr. H. A. Mudge, who was elected President.

Mr. Melcher was a prominent operating officer, and had achieved great and deserved reputation and prestige by his work as Chairman of the Special Committee on the Relations of Railway Operation to Legislation. While he occupied that position he developed a remarkable breadth of view in reference to the regulation of railroads, and great skill in dealing with commissions, lawmakers, and representatives of the railway brotherhoods, and in creating a good understanding and healthy co-operation between them and the railroads at a time when peculiarly needed. His success in these matters was due to the fact that he was a skillful diplomatist, and was also clear-headed and honest.

Mr. Melcher met his death in a railroad accident on January 22d, 1912. With James T. Harahan, Jr., and other railroad officials, he was on a tour of inspection, and while his train was standing near Kinmundy, Ill., an express crashed into the rear coach, killing Mr. Harahan, Mr. Melcher, and others.

Frank Otis Melcher was elected a Member of the American Society of Civil Engineers on March 3d, 1897.

NATHAN JACKSON GIBBS, Assoc. M. Am. Soc. C. E.*

Died December 27th, 1911.

Nathan Jackson Gibbs was born in Norwich, Conn., on December 26th, 1883, and received his primary education in the grammar schools and Academy of that city.

In 1902 and 1904 he was a student at the Massachusetts Institute of Technology; and from there went to Auburn and Brooklyn, N. Y., in the employ of Frank B. Gilbreth, a general contractor. This position led to that of Assistant Superintendent for the Auburn Hame Company, which he held from December, 1904, to May, 1905, with direct charge of various installations and layouts in the new factory of that company. From May, 1905, to September, 1906, Mr. Gibbs was Leveler, Transitman, and Acting Resident Engineer at

* Memoir prepared by Nathan A. Gibbs, Esq.

Ithaca, N. Y., with the New York, Auburn and Lansing Railroad, in charge of construction work, as well as designing culverts, small bridges, etc., and preparing right-of-way maps.

The lure of the Panama Canal drew him to the Isthmus in September, 1906, where, with the Isthmian Canal Commission, he rapidly acquired larger and larger responsibilities, rising from Levelman to Transitman and Instrumentman. During this service he was in charge of borings and locating part of the Canal Zone boundary lines. He also supervised the building of the large reservoir dam at Porto Bello, later becoming Supervisor of the quarry at that station, and finally Superintendent of the station, with a force of twelve hundred men under him. The stone for the Gatun Dam was taken from this quarry, and nearly all of it under Mr. Gibbs' supervision, for he fired the initial blast there, and continued in charge until the end was so near that at the time of his death this supply station for that great engineering work was practically abandoned.

After more than four years of service, in January, 1911, he returned to Norwich for recuperation from a severe attack of nervous prostration. Later, he was in Colorado, where for a short time he was engaged in irrigation work; but, in response to an invitation from the Tomkins Cove Stone Company, at Tomkins Cove, N. Y., he turned back to quarry work as his specialty. This position was exceedingly attractive to him because of the wholly modern equipment of the plant, one of the largest in the United States; and, as its Superintendent, he quickly won the confidence of the owners and the men under him.

On July 12th, 1911, Mr. Gibbs was married, in New York City, to Miss Emma Grace Wright, of Auburn, N. Y., and Boston, Mass., and with her was fast making new friends in Tomkins Cove, where they had lived since August of that year. The accident which caused his death, on December 27th, 1911, was peculiarly unexpected, even in quarry work. A shot, fired at the noon hour, left the face, under which some of the men had been working, in a condition which Mr. Gibbs considered unusually dangerous; and on resuming work in the afternoon he ordered the shovel withdrawn to a safer position, taking his own stand beside it when newly placed in order that he might watch for and give warning of a possible slide. It was while he was thus watching over the safety of his men that he was killed. A mass of rock, close beside and a little above him, and about which there appeared to be no cause for anxiety, fell suddenly, and buried him almost in his tracks. Death was instantaneous, and overtook him alone of all at work in that part of the quarry. He was buried at Norwich, on Sunday, December 31st, 1911.

Mr. Gibbs was held in rare esteem because of his rapidly increasing expert knowledge, his genial cordiality and warm sympathy. He made

friends readily, but wisely; and even those whom he supplanted in his rapid rise in rank and place cherished no resentment toward him. In a very real sense the world is the poorer for such an untimely taking away; but in the larger and truer interpretation of the life he shared so freely and joyously, his contribution to the sum total of the world's work and welfare is a permanent enrichment that will outlast even the stone and concrete monuments of his own faithful building.

Mr. Gibbs was a S. A. E. man of the Massachusetts Institute of Technology; a charter member of the American Society of Engineering Contractors; a member of the Connecticut Society of Civil Engineers, and of the American Railway Engineering Association. He was also a member of the Advisory Board of the Young Men's Christian Association of the Canal Zone, a member of the Strangers Club at Colon, and an honorary member of the Chelsea Boat Club of Norwich.

Mr. Gibbs was elected an Associate Member of the American Society of Civil Engineers on May 2d, 1911.

THOMAS WILLIAM ROSTAD TEIGEN, Assoc. M. Am. Soc. C. E.*

DIED SEPTEMBER 20TH, 1911.

Thomas William Rostad Teigen was born in Manitowoc, Wis., on October 6th, 1881. He received his education in the Grammar School and the Mechanics Arts High School of St. Paul, Minn., and at the University of Minnesota.

From April, 1900, to April, 1902, Mr. Teigen served as Rodman, Topographer and Instrumentman on the Great Northern Railway, on the location and construction of the Jennings Branch in Montana and Canada. From April, 1902, to January, 1903, he was in charge of a party on land surveys in Minnesota and Dakota.

In January, 1903, he entered the employ of the Chicago, Rock Island and Pacific Railway (Choctaw District), serving as Instrumentman, Assistant Engineer, Resident Engineer, and Assistant Division Engineer on Maintenance of Way and Construction, until April, 1906, when he was appointed Assistant Engineer with J. G. White and Company on the construction of the Philippine Railway, in charge of the terminals, wharves, etc., at Cebu.

From April to October, 1907, Mr. Teigen was Engineer of Construction of the Twin City and Lake Superior Railroad Company. While with this company he had charge of the construction of 30 miles of electric road, designed the preliminary plans for a bridge over the St. Croix River, and made standard plans for trestles, culverts, pipes, etc.

---

* Memoir prepared by C. S. McKinney, Esq.

In October, 1907, he was appointed Assistant Chief Engineer of the Minneapolis and Rainy River Railway, and made revisions, constructed a 10-mile extension, and made a report and maps for the Interstate Commerce Commission.

In April, 1908, Mr. Teigen went to South America and was put in charge of a party on preliminary surveys and location for the Madeira-Mamoré Railway in Brazil, afterward being appointed Assistant Engineer on Construction with headquarters at Santo Antonio do Rio Madeira. While engaged on this work, he contracted beri-beri, which compelled him to return to the United States in December, 1908.

After a serious operation and a prolonged stay in the hospital at St. Paul Minn., Mr. Teigen went to the El Paso Southwestern Railway, at El Paso, Tex., as Chief Draftsman and Designer. He designed the plans for the Pintado and French River Bridges and for the Bonita water supply.

Preferring field work, he entered the service of the Mexico Northwestern Railway, in charge of a location party on the extension of this road from Terrazas to Madera, in Chihuahua. On the completion of this location, Mr. Teigen was appointed Office Engineer on Construction at Nueva Cases Grandes, in which capacity he designed the terminal buildings and yards at both Pearson and Madera.

When the construction of the extensive terminals at Madera was begun, Mr. Teigen was appointed Engineer in Charge of Terminals, and had supervision of all the work in connection with this modern and up-to-date plant. The work was progressing satisfactorily when alarming symptoms of his old malady caused the local physicians to order Mr. Teigen to go to St. Paul, Minn., but the disease was too far advanced for an operation to be of any benefit, and, after lingering a few days, he died.

Mr. Teigen was elected a Junior of the American Society of Civil Engineers on September 5th, 1905, and an Associate Member on December 1st, 1908.

GEORGE SHREVE WILKINS, Assoc. M. Am. Soc. C. E.*

Died August 17th, 1910.

George Shreve Wilkins was born in Philadelphia, Pa., on March 14th, 1868. Soon after his birth his family moved to Mount Holly, N. J., where he lived until 1882, when he went to school at Lawrenceville, N. J. In 1886 he entered Princeton College, and was graduated in 1890.

* Memoir prepared by S. C. Thompson, M. Am. Soc. C. E.

He spent two years at Joplin, Mo., as a Mining Engineer, and then returned to Princeton as an instructor in the college. During 1895 and 1896 he was a student in the "Ecole de Mines," Paris, from which he was graduated. In 1899 Mr. Wilkins was Professor of Engineering in the University of Alabama, and held this position while engaged at the Paris Exposition of 1900. The decoration of the Legion of Honor was conferred on him by the French Government, he being the youngest man who had ever been thus honored.

In 1902 Mr. Wilkins returned to the University of Alabama, and shortly after that took a position with the Philippine Exhibition. From 1906 until his death, on August 17th, 1910, he was in the service of New York City as Assistant Engineer in the Bureau of Highways, Borough of the Bronx.

George Shreve Wilkins was elected a Junior of the American Society of Civil Engineers on October 4th, 1892, and an Associate Member on October 5th, 1898.

INDEX

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XXXVIII—No. 4

April, 1912

Published at the House of the Society, 220 West Fifty-seventh Street, New York, the Fourth Wednesday of each Month, except June and July.

Entered as Second-Class Matter at the New York City Post Office, December 15th, 1896.
Subscription, $8 per annum.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XXXVIII—No. 4

APRIL, 1912

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS

NEW YORK 1912

American Society of Civil Engineers

OFFICERS FOR 1912

President, JOHN A. OCKERSON

Vice-Presidents

Term expires January, 1913:	*Term expires January, 1914:*
ALFRED P. BOLLER	CHARLES S. CHURCHILL
CHARLES L. STROBEL	CHARLES D. MARX

Secretary, CHARLES WARREN HUNT

Treasurer, JOSEPH M. KNAP

Directors

Term expires January, 1913:	*Term expires January, 1914:*	*Term expires January, 1915:*
WILLIAM E. BELKNAP	GEORGE C. CLARKE	LINCOLN BUSH
HORACE LOOMIS	CHARLES W. STANIFORD	T. KENNARD THOMSON
GEORGE A. KIMBALL	JONATHAN P. SNOW	EMIL GERBER
PERCIVAL ROBERTS, Jr.	ROBERT RIDGWAY	WILLIAM CAIN
CHARLES F. LOWETH	LEONARD W. RUNDLETT	E. C. LEWIS
ARTHUR DeWINT FOOTE	WILLIAM H. COURTENAY	W. A. CATTELL

Assistant Secretary, T. J. McMINN

Standing Committees

(The President of the Society is *ex-officio* Member of all Committees)

On Finance:	*On Publications:*	*On Library:*
LINCOLN BUSH	WILLIAM E. BELKNAP	ALFRED P. BOLLER
HORACE LOOMIS	ROBERT RIDGWAY	CHARLES D. MARX
CHARLES W. STANIFORD	CHARLES S. CHURCHILL	EMIL GERBER
GEORGE A. KIMBALL	CHARLES L. STROBEL	CHARLES F. LOWETH
PERCIVAL ROBERTS, Jr.	JONATHAN P. SNOW	CHAS. WARREN HUNT

Special Committees

On Concrete and Reinforced Concrete: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

On Engineering Education: Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead.

On Steel Columns and Struts: Austin L. Bowman, Alfred P. Boller, Emil Gerber, Charles F. Loweth, Ralph Modjeski, Frank C. Osborn, George H. Pegram, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

On Bituminous Materials for Road Construction: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard.

On Valuation of Public Utilities: Frederic P. Stearns, H. M. Byllesby, Thomas H. Johnson, Leonard Metcalf, Alfred Noble, William G. Raymond, Jonathan P. Snow.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

House of the Society—220 West Fifty-seventh Street, New York.

Telephone Number....................5913 Columbus.
Cable Address....................."Ceas, New York."

Vol. XXXVIII. APRIL, 1912. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

March 20th, 1912.—The meeting was called to order at 8.30 P. M.; Director T. Kennard Thomson in the chair; Chas. Warren Hunt, Secretary; and present, also, 91 members and 11 guests.

A paper by Charles B. Buerger, Assoc. M. Am. Soc. C. E., entitled "Rebuilding Three Large Pumping Engines," was presented by the author, and the subject was discussed orally by T. C. Atwood, M. Am. Soc. C. E., and the author.

The Secretary announced the following deaths:

George Wallace Melville, elected Honorary Member, December 20th, 1899; died March 17th, 1912.

Thomas Moore Jackson, elected Member, June 3d, 1891; died February 3d, 1912.

La Fayette Olney, elected Member, October 7th, 1868; died March 2d, 1912.

Adjourned.

April 3d, 1912.—The meeting was called to order at 8.30 P. M.; Director T. Kennard Thomson in the chair; Chas. Warren Hunt, Secretary; and present, also, 115 members and 17 guests.

The minutes of the meetings of February 21st and March 6th, 1912, were approved as printed in *Proceedings* for March, 1912.

A paper entitled "A Four-Track Center-Bearing Railroad Draw Span," by Louis H. Shoemaker, M. Am. Soc. C. E., was presented by the Secretary, and the subject was discussed orally by H. J. Cole, M. Am. Soc. C. E.

The Secretary announced the election of the following candidates on April 2d, 1912:

As Members

James Bonnyman, Birmingham, Ala.
Frederick Julius Cellarius, Dayton, Ohio
Alexander Scott Dawson, Calgary, Alta., Canada
Frank Thomas McGinnis, New York City
Jean Leclerc de Pulligny, New York City
Robert John Reidpath, Buffalo, N. Y.
Clarke Stull Smith, Memphis, Tenn.

As Associate Members

William Henry Adams, Detroit, Mich.
James Henry Millar Andrews, Philadelphia, Pa.
Svend Barfoed, Reno, Nev.
Harold William Beers, Atlanta, Ga.
Dudley Frank Black, Los Angeles, Cal.
Royall Douglas Bradbury, Boston, Mass.
William Smith Brownell, Jr., Newport, R. I.
Howard Doriss, Boston, Mass.
John Godfrey Ellendt, Rochester, N. Y.
Eber J Ellsworth, Pittsburgh, Pa.
John Conrad Fitterer, Laramie, Wyo.
William Kaiser Freudenberger, Carson City, Nev.
Archibald Gardner, St. Fereol, Que., Canada.
Claude Clement Hockley, Grand Mere, Que., Canada
Frederick William Kassebaum, Jr., Chicago, Ill.
Arch McKinley, Pittsburgh, Pa.
Vicente Molina, Merida, Yucatan, Mexico
Clare Deloss Murray, Newark, N. Y.
Lawrence Kenneth Needham, Empire, Canal Zone, Panama
Edward Newton Noyes, Dallas, Tex.
Charles Walter Palmer, Philadelphia, Pa.
Albert Waring Pierson, Niagara Falls, N. Y.
Henry George Porter, New York City

Harold Alva Rands, Estacada, Ore.
Le Roy Woodson, San Pedro de Macoris, Santo Domingo

As Juniors

Harold Eaton Babbitt, Chicago, Ill.
Harold Burd Catlin, Pelham Manor, N. Y.
Hart Cummin, Bonny Eagle, Me.
George Mayo, Berkeley, Cal.
William Grover Morrison, Des Moines, Iowa
Chelius Hazel Shea, Memphis, Tenn.
Fred Leroy Stearns, New York City
George William Stephens, Jr., Roland Park, Md.

The Secretary announced the transfer of the following candidates on April 2d, 1912:

From Associate Member to Member

John Henry Bowditch, New Brighton, N. Y.
Frank David Chase, Oak Park, Ill.
Arthur Cassidy Everham, Kansas City, Mo.
Edward Creswell Heald, Washington, D. C.
Francis Dey Hughes, Kansas City, Mo.
Elsworth Mortimer Lee, New York City
John Lorenzo McConnell, Chicago, Ill.
George Stewart Minniss, Buffalo, N. Y.
Howard Scott Morse, Louisville, Ky.
Charles Frederick Parker, Durango, Mexico
Edgar Ernest Seyfert, Pittsburgh, Pa.

From Junior to Associate Member

Ralph Agustus Beebee, Chicago, Ill.
Lloyd Tilghman Emory, Philadelphia, Pa.
Eric Ture King, Cornwall-on-Hudson, N. Y.
Alfred Sidney Malcomson, Freeport, N. Y.
Oren McKenney Moulton, Altmar, N. Y.
Daniel Willets Overocker, Utica, N. Y.
Raymond Washington Parlin, Hagerstown, Md.
James Hammond Stone, Santo Domingo, Santo Domingo
Nathaniel Augustine Thayer, New York City

The Secretary announced the following deaths:

William Bell White Howe, elected Member, March 1st, 1893; died February 11th, 1912.

David Spencer Merritt, elected Member, January 4th, 1905; died March 6th, 1912.

Charles Augustine Miner, elected Associate Member, April 7th, 1897; Member, December 4th, 1901; died March 22d, 1912.

Charles Edward Moore, elected Member, January 7th, 1880; died February 27th, 1912.

John Lawrence Power O'Hanly, elected Member, September 5th, 1883; died March 22d, 1912.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract)

April 2d, 1912.—Vice-President Strobel in the chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Bush, Churchill, Endicott, Gerber, Kimball, Knap, Loomis, Ridgway, Snow, Staniford, and Thomson.

A proposed amendment to the Constitution revising Article VII, which relates to the method of nomination and election of officers, which has been under consideration by the Board for some time, was adopted, and the Secretary instructed to secure the necessary signatures for its legal presentation to the Society, and also to present to the next Annual Convention the recommendation of the Board that the proposed amendment be adopted.

A special Reception to the foreign delegates of the International Association for Testing Materials who will visit New York in September next was authorized.

The previous action of the Board in selecting Saratoga, N. Y., as the place for holding the next Annual Convention was reconsidered, and Seattle, Wash., was selected as the place for holding the Convention of 1912.

Vice-President Marx, Director Cattell and Secretary Hunt, were appointed a Committee of the Board of Direction to determine the date of the Convention and to take general charge of the arrangements.

The resignation of one Associate Member was accepted.

Ballots for membership were canvassed, resulting in the election of 7 Members, 25 Associate Members, and 8 Juniors, and the transfer of 9 Juniors to the grade of Associate Member.

Eleven Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

May 1st, 1912.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "Faults in the Theory of Flexure," by Henry S. Prichard, M. Am. Soc. C. E.; and "A Reinforced Concrete Infiltration Well and Pumping Plant," by Frederick N. Hatch, Jun. Am. Soc. C. E.

Mr. Prichard's paper was printed in *Proceedings* for March, 1912, and Mr. Hatch's paper is printed in this number of *Proceedings.*

May 15th, 1912.—8.30 P. M.—At this meeting a paper by J. V. Davies, M. Am. Soc. C. E., entitled "Air Resistances of Trains in Tube Tunnels," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

June 5th, 1912.—8.30 P. M.—This will be a regular business meeting. A paper by C. E. Grunsky, M. Am. Soc. C. E., entitled "The Appraisal of Public Service Properties as a Basis for the Regulation of Rates," will be presented for discussion.

This paper is printed in this number of *Proceedings.*

FORTY-FOURTH ANNUAL CONVENTION

Notice of Change of Time and Place.

In the March Number of *Proceedings* a brief announcement was made that the Forty-fourth Annual Convention would be held at **Saratoga, N. Y., June 4th, 1912.**

Since that time the Board of Direction has reconsidered its action in fixing both the time and the place. This was done because of many requests received from the membership located all along the Pacific Coast and elsewhere in the West, and to the many logical arguments advanced for making the change. The decision was not made, however, until it was ascertained that a majority of the whole Board was in favor of the change.

The Convention of 1912 will be held at **Seattle, Wash., June 25th to 28th, 1912,** inclusive.

A Committee of the Board of Direction to take general charge of the arrangements for the Convention consisting of Vice-President Marx, Director W. A. Cattell, and Chas. Warren Hunt, Secretary, has been appointed, and it is hoped that a circular containing information in regard to programme, etc., will be issued in ample time for members to make arrangements to be present.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society, in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendices* to the Annual Reports of the Board of Direction for the years ending December 31st, 1906, and December 31st, 1910, contain summaries of all searches made to date.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and, on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907); Vol. XXXVII, p. 28 (January, 1911).

be presented at meetings, but written discussions, only, will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, Jr., M. Am. Soc. C. E., 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

February 16th, 1912.—The meeting was called to order; President Grunsky in the chair; E. T. Thurston, Jr., Secretary; and present, also, 83 members and guests.

Preliminary to the business meeting, views of the active construction work on the dam across the Mississippi River, at Keokuk, Iowa, were shown by moving picture films, and President Grunsky delivered his Inaugural Address.

Charles Derleth, Jr., M. Am. Soc. C. E., Chairman of the Committee representing the Association, made a progress report on the work done in connection with the proposed Engineering Congress to be held at the Panama-Pacific Exposition.

Chas. Warren Hunt, M. Am. Soc. C. E., Secretary of the American Society of Civil Engineers, who was the guest of the Association, addressed the meeting, describing briefly the management of the Engineering Congresses of 1893 and 1904.

A paper entitled "Water Power Development Under Government Control," was presented by O. C. Merrill, Assoc. M. Am. Soc. C. E., and the subject was discussed by Messrs. Galloway, Hall, Cattell, Wagoner, and the author.

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers are held on the second Saturday

of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, Gavin N. Houston, M. Am. Soc. C. E., 409 Equitable Building, Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, and, until further notice, will take place at the Colorado Traffic Club.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

February 17th, 1912.—The meeting was called to order; Vice-President Comstock in the chair; and present, also, 8 members and 4 guests.

An informal discussion on Rock Fill Dams was opened by Mr. Comstock, and the subject was discussed by all those present at the meeting.

Adjourned.

March 16th, 1912.—The meeting was called to order; Vice-President C. W. Comstock in the chair; and present, also, 13 members and 7 guests.

The minutes of the February, 1912, meeting were read and approved.

Mr. Comstock read a letter from A. R. Livingston, M. Am. Soc. C. E., introducing the following resolution, which was passed unanimously:

"The members of the Colorado Association of the American Society of Civil Engineers desire to express in such manner as they are able, their feeling of sorrow and regret at the loss of William Chattin Wetherill, M. Am. Soc. C. E., whose sudden and unexpected death on the tenth of February deprived the profession of an able engineer and the members of this association and many others in this city and elsewhere throughout the country, of a sincere and true friend.

"In all he undertook he was conscientious and thorough, not given to hasty judgment, but weighing facts carefully before forming his opinions.

"He had a good word and one of encouragement for those who called on him for advice and help, and was never heard to criticise harshly or unjustly anyone or anyone's actions.

"All who have had the privilege of having him for a friend realize their great loss which will not be lessened as the years pass.

"He was born a gentleman and was a gentleman to the end.

"*It is hereby resolved* that the above expression of our esteem and sorrow be entered in the minutes of the meeting and that the Secretary be instructed to send a copy to the members of the family."

An informal discussion on "Construction Contracts," was opened by C. S. Lambie, Assoc. M. Am. Soc. C. E., who was followed by two guests, Messrs. McMurray and Fording, and all the members present.

Adjourned.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all Meetings:

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 413 Dorchester Street, West, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Engineers' Club of Baltimore, Baltimore, Md.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Society of Northeastern Pennsylvania, 302 Board of Trade Building, Scranton, Pa.

Engineers' Society of Pennsylvania, 219 Market Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, 321 Hibernia Bank Building, New Orleans, La.

Memphis Engineering Society, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Pacific Northwest Society of Engineers, 803 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 Rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18-1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From March 7th to April 4th, 1912)

DONATIONS *

THE WORLD'S MINERALS.

By Leonard J. Spencer. Cloth, 8¼ x 5½ in., illus., 11 + 272 pp. New York, Frederick A. Stokes Company, 1911. $2.17.

In this book, the author states, an attempt has been made to present, in popular language, an interesting and readable account of various minerals, their practical applications, their importance as ores of the metals, as precious stones, etc. Descriptions of 116 species of the more common minerals, as well as of a few of the more important ones, are given, and these are illustrated by 40 colored plates prepared under the direction of Dr. Hans Lenk, Professor of Mineralogy and Geology in the University of Erlangen, representing actual specimens belonging to the mineral collection under his charge. Although their use is avoided as much as possible, technical terms are explained, it is stated, in the preliminary chapter, and the attention of the student and collector is called to such of the more prominent physical characters of the minerals as will help him to identify his own specimens. The Chapter headings are: Introduction; The Forms of Minerals; The Physical Characters of Minerals; The Chemical Composition and Classification of Minerals; The Native Elements; The Sulphides, Arsenides, and Sulphur-Salts; The Haloids; The Oxides; The Carbonates; The Sulphates, Chromates, Molybdates, and Tungstates; The Phosphates, Arsenates, and Vandadates; The Silicates; The Titano-Silicates, Titanates, and Niobates; The Organic Substances; Index.

NOTES ON HEATING AND VENTILATION.

By John R. Allen. Third Edition. Cloth, 8¾ x 5¾ in., illus., 6 + 227 pp. Chicago, Domestic Engineering Company, 1911. $2.50.

This book, it is stated, has been written primarily for the steamfitter and the designer of heating systems, and presupposes some elementary knowledge of the details of the construction and operation of the simpler forms of heating plants. The subject-matter is a reprint of a series of articles published in *Domestic Engineering,* and has been rewritten and enlarged for this edition. It is shown, it is stated, that the subject can be developed in a logical way from the fundamental principles of engineering. The author has included the results of a series of experiments, carried on at the University of Michigan, in regard to the actual laws of heat and the values of the constants entering into these laws. These results are given in a number of tables, and serve to give, the author states, the designer actual data from actual experiments on which to base his calculations. There is also included a resumé of the results of German experiments and methods of determining heat losses from buildings. Having used the previous editions as a text for his classes in Heating and Ventilation, the author states that the present edition has been written with a view to making the book more desirable as a college text. The Contents are: Introduction; Heat Losses from Buildings; Different Forms of Heating; The Design of a Direct Steam-Heating System; Design and Installation of an Indirect Steam-Heating System; Steam-Boilers and Steam-Piping; Steam-Piping; Design of a Hot Water Heating System; Hot Water Boilers and Piping; Ventilation; Design of Hot Air Heating System; Fan System of Heating; A Central Heating System; Piping, Covering and Other Appliances; Auxiliary Devices for Heating System; Index.

STANDARD FORMS OF FIELD NOTES FOR CIVIL ENGINEERS.

By Chas. C. Anthony. Cloth, 7 x 4¾ in., illus., 12 + 55 pp. New York and London, McGraw-Hill Book Company, 1912. $1.00.

Little space is given usually, the author states, in books dealing with Surveying and Railroad Location, to the art of recording notes, and he, therefore, publishes this book with the hope that note-taking may be simplified and standardized. As many engineers find difficulty in recording the results of their surveys so that they are clear to the draftsman, his aim has been to present forms for note-taking, together with such instructions, that an engineer can take a complete set of notes and record the results of a survey in a workmanlike manner. The Contents are: Station Layout Surveys; Level Notes; Stadia Survey Notes; Curve Rerunning and Spiral Notes; Construction Cross-Section Notes to be Used in the Calculation of Earthwork; Transit Notes; Hydrographic Surveying.

* Unless otherwise specified, books in this list have been donated by the publisher.

MARINE STEAM TURBINES:

Forming the Supplementary Volume to "Marine Engines and Boilers." By G. Bauer and O. Lasche, Assisted by E. Ludwig and H. Vogel. Translated from the German and Edited by M. G. S. Swallow. Cloth, $9\frac{1}{2} \times 6\frac{1}{4}$ in., illus., 16 + 214 pp. New York, The Norman W. Henley Publishing Co.; London, Crosby Lockwood and Son, 1911. $3.50.

As a work on Marine Engines is not complete without dealing with the Steam Turbine, and as the use of the latter for the propulsion of naval vessels has greatly increased, this volume, as stated in the title, is published as a supplement to Dr. Bauer's book on Marine Engines and Boilers. Being supplementary, its contents have been made as concise as possible, only those types of turbines which have been adopted definitely being referred to, but if a further edition is necessary, the scope of the book, it is stated, will be extended. Only a short description of the theory of the steam turbine is included, but with this, and the large number of illustrations given, the authors hope that the volume will serve marine engineers as an introduction to the theory of marine turbine design. In the translation all formulas are expressed in the metric and English units, in order that the volume may be more useful to the English speaking engineer. The Contents are: Part I, Introduction; Part II, General Remarks on the Design of a Turbine Installation; Part III, The Calculation of Steam Turbines; Part IV, Turbine Design; Part V, Shafting and Propellers; Part VI, Condensing Plant; Part VII, Arrangement of Turbines; Part VIII, General Remarks on the Arrangement of Steam Turbines in Steamers; Part IX, Turbine-Driven Auxiliaries; Part X, Tables; Index.

DIRECTORY TO THE IRON AND STEEL WORKS OF THE UNITED STATES:

Second Supplement to the 1908 Edition. Compiled and Published by the American Iron and Steel Association. Corrected to January 1, 1912. Cloth, $8\frac{3}{4} \times 6$ in., 80 pp. Philadelphia, The American Iron and Steel Association, 1912. $5.00.

As stated on the title-page, this Supplement, with its predecessor published in 1910, brings down to the close of 1911, all essential details of new blast furnaces, rolling mills, and steel works which have been undertaken or completed in the United States since 1908, together with the important changes which have taken place, in ownership and equipment, in plants previously described. It also includes an alphabetical list of electric and special furnaces for the manufacture of pig iron, metal suitable for use in puddling and in open-hearth steel furnaces, etc., but which does not include furnaces for the manufacture or refining of steel. This is followed by a list of all the blast furnaces in the United States arranged alphabetically by States, up to January 1st, 1912, including the kinds of fuel used, the grades of pig iron made, and the year the furnaces were last in blast. There is also a list of recently abandoned or dismantled furnaces. It is stated in the preface that from the Directory published in 1908, and its Supplements of 1910 and 1911, the manufacturer or business man may secure any and all the information he needs concerning the equipment and ownership of all the blast furnaces, rolling mills, steel works, and tin plate mills in the United States. The Contents are: Preface; The United States Steel Corporation; Independent Companies (Arranged Alphabetically by Company); Independent Companies (Arranged by States); Latest Information; Electric and Special Furnaces; Complete List of Blast Furnaces; Abandoned or Dismantled Blast Furnaces.

MAXIMUM PRODUCTION IN MACHINE-SHOP AND FOUNDRY.

By C. E. Knoeppel. (Works Management Library.) Cloth, $7\frac{1}{2} \times 5$ in., illus., 6 + 365 pp. New York, The Engineering Magazine, 1911. $2.50.

The material on which this book is based appeared originally in a series of articles in *The Engineering Magazine,* at various times from October, 1908, to May, 1911. For its present form, the subject-matter has been re-arranged, it is stated, from the viewpoint of a larger experience and maturer study of mechanical industries, as well as more advanced principles and methods of management, the result being, the editor states, a logical, well proportioned, and well balanced development of the subject. Everything contained in the book is said to represent

some phase or period of the author's personal experience in busy manufacturing plants. The author devotes the first chapters of his book to a discussion of the principles of organization and management in both the shop and the foundry, these discussions being followed by special applications of the same ideas, first in the shop and then in the foundry, the latter receiving more and closer attention, it is stated, because it has been less thoroughly studied by systematic methods. The Chapter headings are: The Two Great Forces in Manufacturing; Importance of Efficient Organization; The Elements of Accounting and Management; Maintenance, New Construction and Reconstruction; Systematic Processing, Assembly, and Erection; Efficiency in the Use of Materials and Time; Better Deliveries—More Satisfied Customers; Scientific Management in the Foundry; Foundry Organization and Management; Foundry Production and Its Details; Efficient Despatching in the Foundry; Handling Shop Details; Importance of Correct Burden Apportionment; Elements of Foundry Production Costs; Apportionment of Foundry Costs to Production; Cost Apportionment in Various Classes of Foundries.

APPLIED METHODS OF SCIENTIFIC MANAGEMENT.

By Frederic A. Parkhurst. Cloth, 9¼ x 6 in., illus., 12 + 325 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1912. $2.00.

This work is stated to be an amplification of the author's article on the same subject, which appeared in *Industrial Engineering* in 1911. An appendix has been added to the original publication which is stated to contain much new matter. While the principles of scientific management always remain the same, the author states that the methods used to incorporate these principles into a practical organization must be modified or expanded to meet specific requirements. In this book he has described in detail the application of such methods, using as an illustration a history of their application to the Ferracute Machine Company, manufacturers of presses and dies of Bridgeton, N. J. The methods described follow those laid down by Mr. Taylor, and are stated to be particularly adapted to a business employing about 100 people. The author's purpose is not to describe a system of scientific management which can be installed by a novice, but he hopes that the book may be an aid to the business man in locating the deficiencies in his own specific line and induce him to adopt scientific methods in the management of his business. The Contents are: The Preliminary Investigation, etc.; The Functions of the Sales Department and Counting Room, etc.; The Planning Department; Systematic Routing a Necessity; Importance of a Modern System of Stores; The Standardization of Methods and Tools, etc.; Preliminary Work Necessary Before Attempting to Make Time Studies; A Concrete Example of the Course an Order Takes from its Possible Existence as an Enquiry to its Shipment Complete, etc.; Appendix.

THIRD NATIONAL CONFERENCE ON CITY PLANNING:

Proceedings, Philadelphia, Pennsylvania, May 15-17, 1911. Cloth, 9½ x 6½ in., 11 + 293 pp. Cambridge, The University Press, 1911. $1.50. (Donated by the National Conference on City Planning.)

The purpose of these conferences, of which this is the third, others having been held in 1909 and 1910, is stated to be the opportunity afforded for personal discussion of such phases of the subject as the intelligent control and guidance of the entire physical growth, alteration, and equipment of cities, as well as the problems of relieving and avoiding congestion, etc., by those concerned with the different sides of the subject. The object of the discussion is said to be a clearer understanding of the views expressed and to aid in making city conditions healthier, more pleasant, and more economical for those who live among them. A partial list of the Contents is: The Municipal Real Estate Policies of German Cities, by Frederick C. Howe; Public Buildings, by Ernest Flagg; The Location of Public Buildings in Parks and Other Public Open Spaces, by Frank Miles Day; Buildings in Relation to Street and Site, by Lawrence Veiller; Condemnation, Assessments and Taxation in Relation to City Planning, by Lawson Purdy; The Water Terminal Problem, by George E. Hooker; A Survey of American Dock Development, by George C. Sikes; The Organization of the Port of New York, by Calvin Tomkins; Philadelphia Harbor Improvements by Joseph Hasskarl; Los Angeles Harbor, by T. E. Gibbon; Baltimore Harbor Improvements, by Oscar F. Lackey; Street Widths and Their Subdivision, by Nelson P. Lewis; The Narrowing of Minor Residence Streets as Affecting Tenant and Owner, by Charles Mulford Robinson; Standardized Street Widths, by John Nolen; The Legal Aspect of City Planning, by Walter L. Fisher; Certain Principles of a Uniform City Planning Code, by Andrew Wright Crawford; etc., etc.

TREATISE ON HYDRAULICS.

By Mansfield Merriman, M. Am. Soc. C. E. Ninth Edition, Revised and Reset With the Assistance of Thaddeus Merriman, M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 10 + 565 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1912. $4.00.

The authors, it is stated, have endeavored, in this book to unify their presentation of the subject of Hydraulics in a manner advantageous to the technical student and the practicing engineer, and to present it more clearly and concisely, in order to advance the interest of thorough education and to promote sound engineering practice. In order that the advances made in the subject in the last decade might be shown, it was necessary to revise and reset the whole text and to include new matter on hydraulic instruments, methods of measuring water, oblique weirs, etc. Some old matter is stated to have been omitted or condensed, and a few changes in the arrangement of the subject-matter have been made, such as placing the hydraulic tables in the text with the explanations of them, instead of at the end of the book, etc. The tables of coefficients for orifices, weirs, etc., have been revised and extended to include the results of recent experiments. Many examples and problems are given, as well as historical notes and references. The most important data, coefficients, and formulas are given in both English and metric measures. The Contents are: Fundamental Data; Hydrostatics, Theoretical Hydraulics; Instruments and Observations; Flow Through Orifices; Flow of Water Over Weirs; Flow of Water Through Tubes; Flow of Water Through Pipes; Flow in Conduits; The Flow of Rivers; Water Supply and Water Power; Dynamic Pressure of Water; Water Wheels; Turbines; Naval Hydromechanics; Pumps and Pumping; Appendix; Mathematical Tables; Hydraulic Tables in Text; Index.

Gifts have also been received from the following:

Am. Assoc. for the Advancement of Science. 1 vol.
Am. Telephone & Telegraph Co. 1 pam.
Amsterdam, N. Y.-Water Commrs. 1 pam.
Assoc. of Ry. Telegraph Supts. 1 vol.
Auburn, N. Y.-Supt. of Water Board. 1 pam.
Bengal, India-Secy. 1 bound vol., 1 pam.
Berlin Kgl. Technische Hochschule. 1 pam.
Burlington, Vt.-City Clerk. 1 bound vol.
California-State Board of Forestry. 1 vol.
Canada-Bureau of Mines. 1 pam.
Canada-Conservation Comm. 1 bound vol.
Canada-Dept. of Mines. 1 pam.
Canada-Dept. of Rys. and Canals. 1 vol.
Chicago, Ill.-City Clerk. 1 pam.
Chicago Assoc. of Commerce. 1 vol.
Chicago, Indiana & Southern R. R. Co. 1 pam.
Cleveland, Ohio-Dept. of Bldgs. 1 pam.
Cleveland Eng. Soc. 1 bound vol.
Connecticut-State Geol. and Natural History Survey. 1 pam.
Danvers, Mass.-Water Commrs. 1 pam.
Eng. Soc. of Wisconsin. 1 pam.
Engrs.' Club of St. Louis. 2 pam.
Engrs. Soc. of Northeastern Pennsylvania. 3 bound vol.
Engrs. Soc. of Pennsylvania. 1 bound vol.
Ericson, John E. 4 pam.
Fairmount Park Art Assoc. 1 pam.
Fargo, N. Dak.-City Engr. 1 pam.
Glasgow & South-Western Ry. Co. 1 pam.
Grand Junction, Cal.-Commr. of Health and Civic Beauty. 2 pam.
Great Britain-Patent Office. 2 vol.
Hazen & Whipple. 1 pam.
Highland Ry. Co. 2 pam.
Illinois-Secy. of State. 2 vol., 1 pam.
Indiana Eng. Soc. 1 vol.
Iowa-State Coll. 1 vol.
Iowa-State Coll. of Agri. and Mechanic Arts. 1 pam.
Iowa Street and Interurban Ry. Assoc. 3 bound vol.
Lake Erie & Western R.R. Co. 1 pam.
Lake Shore & Michigan Southern R. R. Co. 1 pam.
Lakes-to-the-Gulf Deep Waterway Assoc. 1 bound vol., 1 vol.
Lehigh Univ. 1 vol.
Little Falls, N. Y.-Board of Public Works. 1 pam.
London, Ont.-Water Commrs. 1 pam.
McKim, Alex. Rice. 1 pam.
Maine-State Treasury Dept. 1 bound vol.
Maryland-Bureau of Statistics and Information. 1 bound vol.
Merchants' Assoc. of New York. 1 vol.
Milwaukee, Wis., Bureau of Economy and Efficiency. 1 pam.
Mississippi River Power Co. 1 pam.
National Assoc. of German-American Technologists. 1 pam.
New York City-Health Dept. 1 pam.
New York City-President of the Borough of the Bronx. 1 vol.
New York City-Supt. of Bldgs. 3 pam.
New York State-Barge Canal Terminal Comm. 2 bound vol.
New York State-Forest, Fish and Game Comm. 1 bound vol.
New York State-Public Service Comm., Second Dist. 1 bound vol.
Newburgh, N. Y.-Board of Water Commrs. 1 pam.
North British Ry. Co. 1 pam.
North Carolina-Geol. and Economic Survey. 2 vol.
North-East Coast Institution of Engrs. and Shipbuilders. 4 pam.
Nuneaton, England-Borough Surveyor. 1 pam.
Pacific Northwest Soc. of Engrs. 1 pam.
Pennsylvania R. R. Co. 2 pam.

Rensselaer Soc. of Engrs. 1 bound vol.
St. Paul, Minn.-City Comptroller. 1 bound vol.
Smithsonian Inst. 5 pam.
Soc. of Engrs. (Inc.). 1 pam.
Syracuse Univ. 1 vol.
Tennessee, Univ. of. 1 vol.
Texas & Pacific Ry. Co. 1 pam.
U. S.-Census Bureau. 2 pam.
U. S.-Coast and Geodetic Survey. 1 pam.
U. S.-Geol. Survey. 2 bound vol., 8 vol., 10 pam.
U. S.-Interstate Commerce Comm. 1 bound vol., 1 pam.
U. S.-Navy Dept. 1 pam.
U. S.-Office of Library and Naval War Records. 1 pam.
U. S.-Reclamation Service. 1 vol.
U. S. Steel Corporation. 1 pam.
Vanderbilt Univ. 1 vol.
Vermont, Univ. of. 1 pam.
Waltham, Mass.-Water Dept. 3 pam.
Washington-Public Service Comm. 2 pam.
West Virginia-Dept. of Mines. 1 vol.
Wilmington, Del.-Park Commrs. 1 pam.
Wisconsin-State Supervisor of Illuminating Oils. 1 pam.

BY PURCHASE

Orientation of Buildings or Planning for Sunlight. By William Atkinson. John Wiley & Sons, New York; Chapman & Hall, Limited, London, 1912.

The American Year Book, 1911: A Record of Events and Progress. Edited by Francis G. Wickware, Under Direction of a Supervisory Board Representing National Learned Societies. D. Appleton and Company, New York and London, 1912.

Irrigation and Drainage: Principles and Practice of Their Cultural Phases. By F. H. King. Seventh Edition. The Macmillan Company, New York and London, 1911.

Neuere Kraftanlagen: Eine technische und wirtschaftliche Studie auf Veranlassung der Jagorstiftung der Stadt Berlin unter Mitwirkung von Dr. Ing. Gensecke und Dr. Ing. Hanszel, bearbeitet von E. Josse. Zweite Auflage. R. Oldenbourg, München und Berlin, 1911.

Mining Without Timber. By Robert Bruce Brinsmade. McGraw-Hill Book Company, New York and London, 1911.

The Metallurgy of Iron and Steel. By Bradley Stoughton. Second Edition. McGraw-Hill Book Company, New York and London, 1911.

Das Eisenbahnwesen der Gegenwart dargestellt auf Grund der Verhältnisse der deutschen Bahnen. Herausgegeben unter Förderung des Preussischen Ministers der öffentlichen Arbeiten, des Bayerischen Staatsministers für Verkehrsangelegenheiten, und der Eisenbahn-Zentralbehörden anderer Deutscher Bundesstaaten. 2 Vol. Reimar Hobbing, Berlin, 1911.

The Metallurgy of Steel. By F. W. Harbord and J. W. Hall. Fourth Edition, Enlarged and Revised. The Metallurgical Series, Edited by Professor Sir W. Roberts-Austen. J. B. Lippincott Co., Philadelphia; Charles Griffin & Co., Ltd., London, 1911.

The Encyclopædia of Municipal and Sanitary Engineering: A Handy Working Guide in all Matters Connected with Municipal and Sanitary Engineering and Administration. Edited by W. H. Maxwell and J. T. Brown. D. Van Nostrand Company, New York, 1910.

Neue Theorie und Berechnung der Kreiselräder, Wasser- und Dampfturbinen, Schleuderpumpen und -Gebläse Turbokompressoren, Schrau-

bengebläse und Schiffspropeller. Von Hans Lorenz. Zweite, neubearbeitete und vermehrte Auflage. R. Oldenbourg, München und Berlin, 1911.

Elektrotechnik in Einzeldarstellungen. Herausgegeben von Gustav Benischke. Heft 16, Die Konstruktionen Elektrischer Maschinen, von W. Peineke. Friedr. Vieweg & Sohn, Braunschweig, 1912.

The Primer of Irrigation. By D. H. Anderson. Irrigation Age Company, Chicago, 1910.

SUMMARY OF ACCESSIONS

(From March 7th to April 4th, 1912)

Donations (including 7 duplicates)	145
By purchase	13
Total	158

MEMBERSHIP

ADDITIONS

(From March 11th to April 4th, 1912)

MEMBERS

		Date of Membership.
BASKERVILL, GEORGE BOOTH, JR. Cons. and Constr. Engr. (McLeod & Baskervill), Macon, Miss.		Mar. 5, 1912
BRILLHART, JACOB HERBST. Chf. Engr., The Guerber Eng. Co. (Res., 342 North Seventh Ave), Bethlehem, Pa.	Jun. Assoc. M. M.	Nov. 1, 1901 Nov. 4, 1908 Feb. 6, 1912
CHASE, CHARLES PERRY. Pres. and Treas., Iowa Eng. Co., 123 Sixth Ave., Clinton, Iowa		Mar. 5, 1912
CLARK, ERNEST ALDEN. (George W. Jackson & E. A. Clark Co.), 754 West Jackson Boulevard, Chicago, Ill.		Mar. 5, 1912
HEWITT, GEORGE. (Lee & Hewitt), 1123 Broadway, New York City	Assoc. M. M.	Oct. 3, 1906 Mar. 5, 1912
NORRIS, ALEXANDER JOSEPH. Chf. Engr., Ferrocarril Central del Peru, Lima, Peru		Oct. 3, 1911
OSER, HENRY ISAAC. Asst. Engr., Bureau of Bldgs., Borough of Manhattan, 108 West 111th St., New York City		Feb. 6, 1912
STOCKTON, ROBERT SUMMERS. Supt., Western Sec., Irrig. Blk., Dept. of Natural Resources, C. P. Ry., Strathmore, Alta., Canada	Assoc. M. M.	April 6, 1909 Mar. 5, 1912
VOLCKMAN, GEORGE WILLIAM. Vice-Pres. and Gen. Mgr., MacArthur, Perks & Co., Ltd.; Chf. Engr., Dominion Dry Dock Co., 197 Sparks St., Ottawa, Ont., Canada		Mar. 5, 1912
YOUNG, HENRY AMERMAN. (Young & Hyde), Produce Exchange Bldg., New York City (Res., 18 Belmont Ave., Yonkers, N. Y.)	Jun. Assoc. M. M.	Mar. 5, 1901 Dec. 2, 1903 Mar. 5, 1912

ASSOCIATE MEMBERS

ANNEAR, EDGAR HAROLD. County Engr., Stanislaus County, P. O. Box 81, Modesto, Cal.		Mar. 5, 1912
AUSTIN, FRANK WILLIS. Instrumentman, C., R. I. & P. Ry., Hartford, Conn.		Mar. 5, 1912
BARNETT, RALPH PITCAIRN. Asst. to Chas. W. Leavitt, 220 Broadway, New York City		Mar. 5, 1912
BARTER, HAROLD HENDRYX. Care, Stone & Webster Eng. Corporation, White Salmon, Wash.		Mar. 5, 1912
BRYAN, LEMUEL BERRY JOSEPH. Care, City Engr.'s Office, Chattanooga, Tenn.		Oct. 3, 1911
CHADSEY, WILLIAM WEBSTER. Asst. City Engr., 20 Swan St., Schenectady, N. Y.		Mar. 5, 1912
COOMBS, ARTHUR WELLESLEY. Engr. and Contr., R. D. Coombs & Co., 50 Church St., New York City	Jun. Assoc. M.	Oct. 1, 1907 Mar. 5, 1912

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
CRAVEN, JAY ALLEN. San. Engr. and Water Chemist, State Board of Health, Indianapolis, Ind.	Jun. Assoc. M.	May 31, 1910 Mar. 5, 1912
DECKER, ARTHUR JAMES. Instr. in Civ. Eng., Univ. of Michigan, 816 East Ann St., Ann Arbor, Mich.	Jun. Assoc. M.	Sept. 5, 1905 Mar. 5, 1912
DIESEM, HARRY CUSTER. Irrig. Engr., Office of Experiment Stations, Dept. of Agri., North Platte, Nebr.		Mar. 5, 1912
GERHARZ, HENRY. Pres. and Gen. Mgr., The Henry Gerharz Eng. Co., P. O. Box 1226, Billings, Mont.		Mar. 5, 1912
HALE, HERBERT MILLER. Asst. Gen. Supt., Holbrook, Cabot & Rollins Corporation, 331 Madison Ave., New York City.	Jun. Assoc. M.	Nov. 1, 1904 Mar. 5, 1912
HOGAN, JOHN PHILIP. Hotel Colonial, 81st St. and Columbus Ave., New York City.	Jun. Assoc. M.	Dec. 6, 1904 Mar. 5, 1912
MILLER, HENRY LANARK. Engr., Sec. of Rds. and Bridges, Dept. of Public Works, Casilla Correo 117, Mendoza, Argentine Republic.	Jun. Assoc. M.	June 4, 1907 Dec. 5, 1911
NEWTON, GEORGE CHENEY. Engr., Newton Eng. Co., 434 Jackson St., Milwaukee, Wis.	Jun. Assoc. M.	Feb. 4, 1908 Mar. 5, 1912
OSGOOD, TOM WILLIAM. (Osgood & Cummings), P. O. Box 568, Medford, Ore.		Jan. 2, 1912
REED, HOWARD SAWYER. Engr., U. S. Reclamation Service, Phœnix, Ariz.		Oct. 3, 1911
ROCKWELL, REUBEN LYNN. Constr. Engr., Portneuf Marsh Val. Irrig. Co., Downey, Idaho.		Mar. 5, 1912
SPALDING, WALTER JAMES. Asst. Engr., Second Dist., Pacific Div., Isthmian Canal Comm., Balboa, Canal Zone, Panama.	Jun. Assoc. M.	Nov. 1, 1904 Feb. 6, 1912
STARK, ALEXANDER DOUGLAS. 230 Devon St., Kearny, N. J.		Mar. 5, 1912
STEPHENS, FRANK WILLIAM. Central Aguirre, Porto Rico.		Mar. 5, 1912
TEFFT, WILLIAM WOLCOTT. Civ. and Hydr. Engr., 766 West Main St., Jackson, Mich.	Jun. Assoc. M.	Mar. 31, 1908 Jan. 2, 1912
TINSLEY, ROBERT BRUCE. Engr. in Chg., Pedro Miguel Lock and Dams, Isthmian Canal Comm., Pedro Miguel, Canal Zone, Panama.		Feb. 6, 1912
VANSITTART, GEORGE EDWARD. Chf. Field Engr., The Crane Falls Power & Irrig. Co., Ltd., 603 Idaho Bldg., Boise, Idaho.		Mar. 5, 1912

ASSOCIATES

JENNINGS, CHARLES AUGUSTUS. Chf. Chemist and Supt. of Filtration, Union Stock Yard & Transit Co., Union Stock Yards, Chicago, Ill.		Mar. 5, 1912

ASSOCIATES (*Continued*)	Date of Membership.
PRICE, FRANK. Chf. Insp., Isthmian Canal Comm., Braddock, Pa.	Feb. 6, 1912

JUNIORS

ANDERSON, LYTTLETON COOKE. Asst. Engr., Memphis Steel Constr. Co., P. O. Box 397, Memphis, Tenn.	Mar. 5, 1912
BURROWES, ROBERT WILLIAM. Chf. Asst. to George S. Vanderwerken, Long Beach, N. Y.	Mar. 5, 1912
DuBOIS, GEORGE BACHE. Rodman, P. R. R., 2041 West Ontario St., Philadelphia, Pa.	Mar. 5, 1912
GRIEWANK, ARTHUR CARL. Engr. with A. L. Boobs, 2873 Clay St., San Francisco, Cal.	Oct. 31, 1911
HARRIS, FRANK SAMPSON MASON. Draftsman, Galloway & Markwart, 454 Sixty-first St., Oakland, Cal.	Mar. 5, 1912
JOHNSON, THEODORE SEDGWICK. Prof. of Civ. Eng., Denison Univ., Box 595, Granville, Ohio	Jan. 2, 1912
LYON, FREDERIC WILLIAM. 529 Oliver Bldg., Pittsburgh, Pa.	Oct. 3, 1911
SCHARFF, MAURICE ROOS. 2164 Highland Ave., Birmingham, Ala.	Feb. 6, 1912
SHERIDAN, LAWRENCE VINNEDGE. 2347 North Pennsylvania St., Indianapolis, Ind.	Mar. 5, 1912

CHANGES OF ADDRESS

MEMBERS

ALFRED, FRANK HOOKER. Asst. Gen. Mgr., P. M. R. R., Detroit, Mich.

ALLEN, CHAUNCEY LOOMIS. Pres., Syracuse & Suburban R. R., Syracuse, N. Y.

BACON, JAMES HAYWARD. R. F. D. No. 4, Jacksonville, Fla.

BELDEN, HARRY AUSTIN. Care, Hammond Constr. Co., 30th and 2d Streets, Washington, D. C.

BIENENFELD, ABEL MORRIS. Cons. Engr., Wells Fargo Bldg., San Francisco, Cal.

BROSIUS, ALBERT MARSHALL. Ingeniero Jefe, Alcantarillado y Pavimentacion, 24 Cuba St., Havana, Cuba.

BROWN, STEPHEN PEARSON. Managing Engr., Canadian Northern Montreal Tunnel and Terminal Constr., for Mackenzie, Mann & Co., Ltd., 230 James St., Room 30, Montreal, Que., Canada.

CHAMBERS, FRANK TAYLOR. Civ. Engr., U. S. N., U. S. Naval Training Station, Great Lakes, North Chicago, Ill.

CONGDON, JOHN POTTER. Cons. Engr., 620 Empire Bldg., Boise, Idaho.

DABNEY, AUGUSTINE LEE. Chf. Engr., The Dabney Eng. Co., 81 Porter Bldg., Memphis, Tenn.

DAVIS, CHANDLER. Cons. Engr., 1 Broadway, Room 116, New York City.

DAVIS, CHARLES HENRY. 18 Old Slip, New York City.

DEAN, LUTHER. 1312½ Commerce St., Dallas, Tex.

MEMBERS (*Continued*)

DOUGAN, WILLIAM THOMAS. Engr., M. of W., New York Rys. Co., 165 Broadway, New York City.

DURHAM, HENRY WELLES. Chf. Engr., Bureau of Highways, 21 Park Row, New York City.

ELLERY, NATHANIEL. Cons. Engr., 1034 Merchants Exchange Bldg., San Francisco, Cal.

FERGUSON, JOHN NEIL. Asst. Engr., Directors of the Port of Boston, 40 Central St., Boston, Mass.

FOLWELL, AMORY PRESCOTT. Editor, *Municipal Journal and Engineer*, 50 Union Sq., New York City.

GIBSON, JASPER MANLIUS. Secy. and Treas., Mulcahy & Gibson, Inc., 168 Madison Ave., New York City.

GILLETTE, HALBERT POWERS. Editor, *Engineering-Contracting*, 608 South Dearborn St., Chicago, Ill.

GREEN, BERNARD LINCOLN. Vice-Pres., The Osborn Eng. Co., 740 Engineers Bldg., Cleveland, Ohio.

HAMMATT, WILLIAM CUSHING. Cons. Engr., Room 819, Foxcroft Bldg., San Francisco, Cal.

HARTMAN, RUSSELL THEODORE. Cons. Engr., 1246 Forty-Sixth St., Des Moines, Iowa.

HAYDEN, WILLIAM WALLACE. Div. Engr., M., O. & G. Ry., Fairland, Okla.

HENDERER, WILLIAM OSWALD. Pres., The Osborn Eng. Co., 740 Engineers Bldg., Cleveland, Ohio.

HERRMANN, FREDERICK CHARLES. Engr., Spring Val. Water Co., 375 Sutter St., San Francisco, Cal.

HOBBY, ARTHUR STANLEY. Cons. Engr., Box 685, Guayaquil, Ecaudor.

HORNSBY, ROBERT WRIGHT. Casilla No. 2, Potosi, Bolivia.

KELLOGG, NORMAN BENJAMIN. Cons. Engr., Care, Grand Union Hotel, San Francisco, Cal.

KIRKPATRICK, WALTER GILL. City Engr., Birmingham, Ala.

LEIGHTON, GEORGE. Res. Engr., D., L. & W. R. R. Co., Glenburn, Pa.

MCCOMB, DAVID E. "The Porter," Washington, D. C.

MCLEAN, ARCHIBALD. Asst. Engr., Dept. of Bridges, City of New York, 305 East 60th St., New York City.

MEIGS, JOHN. U. S. Asst. Engr., 553 Bourse Bldg., Philadelphia, Pa.

MORRIS, MARSHALL, JR. Care, Gordon-Jones Constr. Co., 310 Gibbs Bldg., San Antonio, Tex.

MURPHY, DANIEL WILLIAM. Engr. in Chg., Drainage, U. S. Reclamation Service, Los Angeles, Cal.

OSBORN, FRANK CHITTENDEN. Cons. Engr., 740 Engineers Bldg., Cleveland, Ohio.

PEARSON, FRED STARK. Cons. Engr., 115 Broadway, New York City.

PHILLIPS, ARTHUR LOUIS. Chf. Engr., The Cuba R. R., Camaguey, Cuba.

POLLOCK, CLARENCE DUBOIS. Ingeniero Encargado de la Pavimentacion. Calle Cuba 24, Havana, Cuba.

RICHARDSON, JOSHUA WILSON. Bel Air, Md.

MEMBERS (*Continued*)

RITCHIE, JAMES. Cons. Engr., 526 Citizens Bldg., Cleveland, Ohio.

ROBINSON, JOHN MASON. Asst. Chf. Engr., Madeira-Mamoré Ry., Caixa 304, Manãos, Brazil.

SAFFORD, HARRY ROBINSON. Chf. Engr., G. T. Ry., Montreal, Que., Canada.

SHANKS, OSCAR. 2216 Jefferson Ave., Norwood, Ohio.

SHEPARD, HENRY HUDSON. Gen. Supt., Charlotte Harbor & Northern Ry., Boca Grande, Fla.

SUNDSTROM, ALFRED YNGVE. Res. Engr., U. S. Steel Products Co., 42 Rua Candelaria, Rio de Janeiro, Brazil.

SWEETSER, CHARLES HERBERT. Cons. Engr., P. O. Box 558, Tacoma, Wash.

TAINTER, FRANK STONE. (F. S. Tainter & Co.), 55 Wall St., New York City.

THURBER, CLINTON DRAPER. Civ. Engr., U. S. N., U. S. Navy Yard, Brooklyn, N. Y.

TILTON, BENJAMIN ELLSWORTH. Gen. Mgr., Syracuse Rap. Trans. Ry., Syracuse, N. Y.

TOMLINSON, SAM. 100 Robinson Rd., Singapore, Straits Settlements.

VAN ALSTYNE, HENRY ARTHUR. Care, Acme Eng. & Contr. Co., Herkimer, N. Y.

WADDELL, MONTGOMERY. Cons. Engr., 30 Church St., New York City.

WAGNER, HARRY EDWARD. Res. Engr., D., L. & W. R. R., P. O. Box 94, Clark's Summit, Pa.

WATT, DAVID ALEXANDER. U. S. Engr. Office, 39 Whitehall St., Room 710, New York City.

WILSON, ELLIOTT HINCKLEY. Civ. and Min. Engr., Care, Silver Bow Club, Butte, Mont.

ASSOCIATE MEMBERS

ATTERBURY, CHARLES DE LA PLANE. San Rafael, Cal.

AWOYAMA, AKIRA. 653 Tabata, Takinogawamura, Tokyo, Japan.

BALDWIN, GEORGE HERBERT. Semitropic, Cal.

BERRY, CLAUDE. Chf. Engr., Darbyshire-Harvie Iron & Machine Co, El Paso, Tex.

BISHOP, LYMAN EDGAR. Location Engr., The Goldsborough Co., Box 33, Laramie, Wyo.

BIXBY, FREDERICK LOUIS. Irrig. Engr., U. S. Dept. of Agri.; Prof. of Civ. and Irrig. Eng., New Mexico Coll. of Agri. and Mechanic Arts, State College, N. Mex.

BOUILLON, ARTHUR MAXIMILLIEN. Dist. Engr., G. T. P. Ry., Quebec, Que., Canada.

BRAUNWORTH, PERCY LEWIS. San. and Hydr. Engr. (Farley & Braunworth), 90 West St., New York City.

BROWN, COLLINGWOOD BRUCE, JR. Prin. Asst. Engr., C. P. Ry., Montreal, Que., Canada.

BRUCE, JOHN AUGUSTUS. Sewer Engr., City of Omaha; Civ. and Municipal Engr. (The Consolidated Eng. Co.), 432 Bee Bldg., Omaha, Nebr.

BUNKER, STEPHEN SANS. 344 Batavia St., Toledo, Ohio.

ASSOCIATE MEMBERS (*Continued*)

BURROUGHS, FREDERIC. 5447 Stanton Ave., Pittsburgh, Pa.

BURROUGHS, HECTOR ROBINS. Cons. Engr., 68 William St., New York City.

CAMPBELL, DUNCAN HUGH. Supt., Pirahy Tunnel, Avenida Central 76, Rio de Janeiro, Brazil.

CHASE, FRANK DAVID. Archt.; Industrial Engr., 757 Peoples Gas Bldg., Chicago, Ill.

COOMER, ROSS MILLER. 1500 Pierce St., Sioux City, Iowa.

COULTER, WALDO SCARLETTE. Calle Lavalle 448, Buenos Aires, Argentine Republic.

CROSS, JOHN HALSEY. 801 West 5th Ave., Gary, Ind.

DAVIS, CHARLES MOSS. 310 Reynolds Bldg., Ft. Worth, Tex.

DICKE, EDWARD CHRISTIAN. 1223 Blackstone Ave., St. Louis, Mo.

DORRANCE, WILLIAM TULLY. Care, T. L. Dunn, Chf. Engr. Maine Cent. R. R., Portland, Me.

DOW, WILLIAM GREAR. Eden, Wyo.

EDWARDS, DEAN GRAY. 933 East 22d St., Brooklyn, N. Y.

EDWARDS, WILLIAM WATKYN. Care, Sierra & S. F. Power Co., Sonora, Cal.

EVANS, PETER PLATTER. Secy., The Osborn Eng. Co., 740 Engineers Bldg., Cleveland, Ohio.

FORREST, GEORGE MUNRO. 293 Broadway, New York City.

FOSTER, REGINALD GUY. Hotel Bradley, Chicago, Ill.

FULLER, CARL HAMILTON. Asst. Engr., Central Georgia Power Co., Macon, Ga.

GAY, HOWARD SPOONER. 16 West 28th St., Bayonne, N. J.

GILLHAM, PHILIP DAKIN. Dist. Mgr. of Sales, Corrugated Bar Co., 1408 National Bank of Commerce Bldg., St. Louis, Mo.

GOODMAN, LEON. Pres., Goodman-McCormick Co., Inc., 410 Equitable Bldg., Des Moines, Iowa.

GOODSELL, DANIEL BERTHOLF. 112 West 73d St., New York City.

HARTUNG, PAUL AUGUST. Div. Engr., Northern Extension, M., O. & G. Ry., Wagoner, Okla.

HAZELTON, WILLIAM SYLVESTER. Care, F. C. Gilchriese, 2549 Main St., Buffalo, N. Y.

HOOD, JAMES HENRY. Supt. of Constr., Stone & Webster Eng. Corporation, 305 Third National Bank Bldg., St. Louis, Mo.

HUNTER, THOMAS BENTON. Chf. Engr., Dept. of Works, Panama-California Exposition Co., 620 Timken Bldg., San Diego, Cal.

JOHNSON, ROBERT CHAN. State Engr. and Chf. Surv., Board of Public Works, Canton, China.

KAST, CLARKE NIGHTINGALE. Asst. Engr., O. R. & N. Co., 1513 Mallon Ave., Spokane, Wash.

KRAUSE, LOUIS GUSTAV. Res. Engr., D., L. & W. Cut-off, Box 305, New Milford, Pa.

LINDHOLM, CARL BERTRAM. (Lindholm & Fuller), Agri. National Bank Bldg., Pittsfield, Mass.

LONG, EUGENE McLEAN. (Long & Miller), 172 Fulton St., New York City.

ASSOCIATE MEMBERS (*Continued*)

McCormick, Herbert Granville. Junior Engr., U. S. Engr. Office, Heidelburg, Ky.

McDonough, Michael Joseph. Capt., Corps of Engrs., U. S. A., War Dept., Washington, D. C.

McMenimen, William Vincent. Care, Raymond Concrete Tile Co., Marquette, Mich.

Meem, James Lawrence. (Meem & Kinnier), Jonesboro, Tenn.

Melius, Ludlow Lawrence. Care, Spuyten Duyvil Constr. Co., 2306 Eighth Ave., New York City.

Millard, William John. Mission Miniere Bas-Congo, Boma, Congo Belge, West Africa.

Moritz, Ernest Anthony. Care, Midland Eng. Co., North Yakima, Wash.

Nash, Frank Dana. 207 I. O. O. F. Bldg., Reno, Nev.

Newcomb, William Taft. Engr., Amies Road Co., 702 Drake Bldg., Easton, Pa.

Nishkian, Leon Hagop. Hotel Herald, Cor., Jones and Eddy, San Francisco, Cal.

Peck, Myron Hall. Engr., Standard Am. Dredging Co., 6426 Colby St., Oakland, Cal.

Pfeifer, Herman Julius. Engr., M. of W., Terminal R. R. Assoc. of St. Louis, St. Louis Merchants Bridge Terminal Ry. Co., 2102 Blenden Pl., St. Louis, Mo.

Pires do Rio, Jose. Chf. Engr. of Inspectoria das Seccas, Bahia, Brazil.

Poe, Harry Tinker, Jr. Traveling Engr., The Buckeye Cotton Oil Co., Box 1555, Atlanta, Ga.

Riedel, John Charles. Instr. of Mechanics, Cooper Union; Asst. Engr., Bureau of Sewers, 505 Macon St., Brooklyn, N. Y.

Riegel, Ross Milton. Care, Mountain Park Land Co., Connellsville, Pa.

Rights, Herbert Timothy. Asst. Engr., Lewis F. Shoemaker & Co., Pottstown, Pa.

Robbins, Dana Watkins. Secy. and Engr., Spuyten Duyvil Constr. Co., 2306 Eighth Ave., New York City.

Saucedo, Vicente. Cons. Engr., Altos Banco Mercantil 7, P. O. B. 183, Monterey, N. L., Mexico.

Sheffield, Edward Newton. Irrig. Engr., The Tyrone Constr. & Irrig. Co., 308 Bank Bldg., Trinidad, Colo.

Shoemaker, John Earl. Swartz Hotel, Elba, N. Y.

Sims, Stuart. Asst. Engr., Kittitas Reclamation Dist., Ellensburg, Wash.

Slocum, Harry Spencer. Care, Vielé, Blackwell & Buck, Byllesby, Va.

Soule, Edward Lee. Cons. Engr., 255 Monadnock Bldg., San Francisco, Cal.

Spencer, Frank Norton. Mgr., Eastern Dept., Leonard Constr. Co., Room 2730, Whitehall Bldg., New York City.

Stevens, John Cyprian. Care, Ebro Irrig. & Power Co., Apartado 491, Barcelona, Spain.

Stevens, Leigh E. Asst. City Engr., 238 James St., Grand Rapids, Mich.

Tunstall, Whitmell Pugh. Constr. Engr., 220 Arcade Bldg., Norfolk, Va.

ASSOCIATE MEMBERS (*Continued*)

Van Reenen, Reenen Jacob. Irrig. Dept., Union of South Africa, Box 40, Cradock, Cape Province, South Africa.

Wall, George Albert. Care, Can. Pac. Ry., Irrig. Dept., Bassano, Alta., Canada.

Waring, Charles Thomas. Res. Engr., Cape Cod Constr. Co., Sandwich, Mass.

Whitaker, Ralph Wallace. 140 College Ave., Davenport, Iowa.

Willis, Harry Parsons. Chf. Engr., Dept. of Highways, Waterford, N. Y.

Wilson, Edbert Carson. (Green & Wilson), 132 Main St., Waterville, Me.

Wise, Robert Emmet. Care, Board of Water Commrs., Hartford, Conn.

Wyckoff, Charles Rapelyea. Asst. Engr., Board of Water Supply, City of New York, Realty Bldg. (Res., 66 Hamilton Ave.), White Plains, N. Y.

Zorn, George Washington. Hydr. and Gen. Eng., Box 1014, Cheyenne, Wyo.

ASSOCIATES

Atwell, Harry Hurd. 521 Linden St., Ann Arbor, Mich.

Graves, Edward Michael. 542 Rockefeller Bldg., Cleveland, Ohio.

JUNIORS

Beall, Pendleton. Instrumentman, N. Y. C. & H. R. R. R., 7 Tompkins Ave., Fishkill-on-Hudson, N. Y.

Bringhurst, John Henry. Care, Kansas City Terminal Ry., Kansas City, Mo.

Clifford, Walter Woodbridge. 60 Oak St., Hyde Park, Mass.

Deutschbein, Harry Johnson. Care, The Foundation Co., 115 Broadway, New York City.

Germer, Wilhelm Eduard. 510 West 140th St., New York City.

Goodrich, Thomas MacLenathen. 326 Abington Bldg., Portland, Ore.

Gram, Ralph Samuel. 1047 Spitzer Bldg., Toledo, Ohio.

Hall, Charles Lacey. First Lieut., Corps of Engrs., U. S. A., Manila, Philippine Islands.

Hawley, Charles Burridge. Decorah, Iowa.

Hayes, Ferdinand Eugene, Jr. With F. E. Hayes, Jr. & Co., Edgoten, Ky.

Hughes, William Richard, Jr. 282 Redmond St., New Brunswick, N. J.

Longwell, John Stalker. Junior Engr., U. S. Reclamation Service, Burley, Idaho.

McClure, Hunter. 2802 Mountain Ave., Birmingham, Ala.

Moore, James Gates. Res. Engr., Fla. Coast Line Canal & Trans. Co., Tatem Bldg., Miami, Fla.

Overocker, Daniel Willets. Asst. Engr., Barge Canal Terminals, 4 Mann Blk., Utica, N. Y.

Payne, James Elwood. Care, General Fireproofing Co., Youngstown, Ohio.

Ruth, Edgar Kingsbury. Asst. Engr., Kaps-Brehm Co., 1321 Locust St., Cincinnati, Ohio.

Sanger, Walter Max. Maxton, Ariz.

JUNIORS (*Continued*)

SCOTT, JAMES ROBINSON, JR. Room 700, Tramways Bldg., Denver, Colo.

STOCKER, EDWARD CHARLES. Box 65, American P. O., Shanghai, China.

STRANDBERG, GEORGE ROBERT. Instr. in Civ. Eng., Univ. of Washington, 1736 West 63d St., Seattle, Wash.

THAYER, NATHANIEL AUGUSTINE. 519 West 121st St., New York City.

TIMBERLAKE, SETH MARTIN. Asst. Engr., Board of Water Supply, White Plains, N. Y.

VANNEMAN, ARTHUR VOSBURY. Havre de Grace, Md.

VEATCH, NATHAN THOMAS, JR. 525 Mound St., Atchison, Kans.

WHITMAN, WILLIAM SATTERWHITE. R. No. 1, Franklin, Tenn.

YEO, WILLIAM ALBERT. Res. Engr., Chi. & Erie R. R., Monterrey, Ind.

RESIGNATION

ASSOCIATE MEMBER	Date of Resignation.
SEARS, THOMAS BARTLETT	April 2, 1912

DEATHS

MELVILLE, GEORGE WALLACE. Elected Honorary Member, December 20th, 1899; died March 17th, 1912.

JACKSON, THOMAS MOORE. Elected Member, June 3d, 1891; died February 3d, 1912.

MERRITT, DAVID SPENCER. Elected Member, January 4th, 1905; died March 6th, 1912.

MINER, CHARLES AUGUSTINE. Elected Associate Member, April 7th, 1897; Member, December 4th, 1901; died March 22d, 1912.

MOORE, CHARLES EDWARD. Elected Member, January 7th, 1880; died February 27th, 1912.

O'HANLY, JOHN LAWRENCE POWER. Elected Member, September 5th, 1883; died March 22d, 1912.

OLNEY, LAFAYETTE. Elected Member, October 7th, 1868; died March 2d, 1912.

Total Membership of the Society, April 4th, 1912, 6 425.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(March 9th to April 3d, 1912)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal,* Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings,* Engrs. Club of Phila., 1317 Spruce St., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Monadnock Blk., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(8) *Stevens Institute Indicator,* Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(10) *Cassier's Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 12c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway and Engineering Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 25c.
(22) *Iron and Coal Trades Review,* London, England, 25c.
(23) *Bulletin,* American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *American Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Mines and Minerals,* Scranton, Pa., 25c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions,* Am. Soc. C. E., New York City, $4.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.
(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 803 Fulton Bldg., Pittsburgh, Pa., 50c.
(59) *Transactions,* Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World,* 59 Ninth St., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 15c.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England.
(70) *Engineering Review,* New York City, 10c.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 10c.
(77) *Journal,* Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen,* Vienna, Austria.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(83) *Progressive Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(94) *The Boiler Maker,* New York City, 10c.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., 219 Market St., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $1.50.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Mining Engrs., London, England, 6 shillings.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Southern Machinery,* Atlanta, Ga., 10c.

LIST OF ARTICLES.

Bridges.

Reinforced Concrete Bridge Across the Almendares River, Havana, Cuba.* Eugene Klapp and W. J. Douglas, Members, Am. Soc. C. E. (54) Vol. 74.
Steel Centering Used in the Construction of the Rocky River Bridge, Cleveland, Ohio. Wilbur J. Watson, M. Am. Soc. C. E.* (54) Vol. 74.
Reinforced-Concrete Bridge at Farnworth.* (11) Mar. 1.
Bascule Bridge Over Harbor Channel at Copenhagen.* C. Van Langendonck. (15) Mar. 8.
Erection of the Harold Avenue Viaduct, New York.* (14) Mar. 9.
A Five-Track Plate-Girder Bridge with Ballasted Floor.* (14) Mar. 9.
The Fifth Avenue Viaduct at Fitchburg.* (14) Mar. 9.
A Pony-Truss Highway Bridge with Concrete Floor.* (14) Mar. 9.
The Brady Avenue Bridge.* (14) Mar. 16.
Braced Bridge Piers on Soft Ground.* (14) Mar. 16.
Reinforced-Concrete Viaduct Carrying a Seattle Street over Railway Yards.* E. E. Adams. (13) Mar. 21.
Erecting 110-ft. Plate-Girders with a Long-Reach Derrick Car.* E. A. Gibbs. (13) Mar. 21.

*Illustrated.

Bridges—(Continued).

An Ornamental Highway Bridge, a Concrete Arch in Kansas City, Missouri, with Foundations 40 Feet Deep.* (14) Mar. 23.
The Reinforced-Concrete Bridge at Tempe, Ariz.* (13) Mar. 28.
Bridge Construction on the Oregon Trunk Railway.* (15) Mar. 29.
Le Pont du Risorgimento, sur le Tibre, à Rome.* Louis Quesnel. (43) Jan.
Note sur les Travaux d'Elargissement des Ponts sur la Seine à Puteaux et à Neuilly-Saint-James.* Caldagués. (43) Jan.
Zur Standsicherheitsuntersuchung schiefer gewölbter Brücken.* A. Hofmann. (81) Pt. 2
Gleichungen über die Formänderung vollwandiger Bögen.* Joh. Duwe. (81) Pt. 2.
Schienenversteifung und Ubergangslaschen an den Stössen auf der Drehbrücke über den Oberhafen in Hamburg.* Carl Ernst Susemihl. (102) Mar. 1.
Neubau der Dove-Brücke in Charlottenburg.* Zangemeister. (51) Serial beginning Mar. 16.

Electrical.

Modern High-Voltage Power Transformers in Practice; With Special Reference to a "T" Three-Unit System.* William T. Taylor. (77) Feb.
The Mechanical Design of Direct Current Turbo-Generators.* R. J. Roberts. (77) Feb.
Notes on National and International Standards for Electrical Machinery.* Robert Pohl. (77) Feb.
Small Electricity Supply Undertakings. Percy A. Spalding. (77) Feb.
The Mutual Attractions or Repulsions of Two Electrified Spherical Conductors. Alexander Russell. (77) Feb.
Brushes* (For Motors). W. R. Whitney. (3) Mar.
Saving Effected by the Electric Lighting of Small Stations. Sussmann. (From *Zeitung* des Vereins deutscher Eisenbahnverwaltungen.) (88) Mar.
Degradation of Accumulated Energy.* Alfred G. Collis. (Paper read before the South Wales Inst. of Engrs.) (57) Mar. 1.
Héroult Electric Furnace at Braintree.* (22) Mar. 8.
Recent Experiments on Directive Wireless Telegraphy with Earth Antennæ.* F. Kiebitz. (Abstract of translation from Communication from the Imperial Telegraphs Experiment Station.) (73) Mar. 8.
The Theory of the Submarine Telegraph Cable. H. W. Malcolm. (73) Serial beginning Mar. 8.
Some Modern Problems of Illumination.* T. Thorne Baker. (29) Mar. 8.
Auxiliary Oil-Burning Station for Southern California District.* (Electrical power plant.) (27) Mar. 9.
Distributed Leakage in Telephone and Telegraph Systems. Frank F. Fowle. (27) Mar. 9.
Commercial Electrical Apparatus for 100 000 Volt Service. S. Q. Hayes. (Abstract of paper read before the Congress Internazionale delle Applicazioni Elettriche.) (73) Mar. 15.
Current and Power Factors in Induction Motors.* H. J. S. Heather. (Abstract of paper read before the South African Inst. of Engrs.) (73) Mar. 15.
200 Ton Electric Revolving Cantilever Crane.* (11) Mar. 15.
Electric Power in a Japanese Shipbuilding Yard.* (26) Mar. 15.
The Thickness of Insulation on Wires and Cables.* J. H. Lendi. (27) Mar. 16.
Specifications for Overhead Wires Adopted by the City of Seattle, Wash. H. L. Estep. (13) Mar. 21.
Electrical Power at the New Immingham Dock of the Great Central Railway Co.* (73) Serial beginning Mar. 22.
On the Designs of Dynamo Electric Machinery. A. E. Clayton. (73) Serial beginning Mar. 22.
Some Considerations on the Choice of Auxiliary Plant for Power Stations. A. H. Finch. (Abstract of paper read before the North-East Coast Inst. of Engrs. and Shipbuilders.) (73) Mar. 22.
Electrical Installation of Mount Wilson Solar Observatory.* Howard S. Knowlton. (27) Mar. 23.
Regulation of Radiotelegraphy.* Robert A. Morton, Jr. (19) Mar. 23.
Design and Construction of a Reinforced Concrete Telegraph Pole Line Across the Hackensack Meadows, New Jersey.* George Gibbs, M. Am. Soc. C. E. (Paper read before the National Assoc. of Cement Users.) (86) Mar. 27.
Lake Shore Station of Cleveland Electric Illuminating Company.* (27) Mar. 30.
An Underground System and a Few Developments.* S. B. Clark. (42) Apr.
Alternating-Current Systems of Underground Distribution.* S. J. Lisberger and C. J. Wilson. (42) Apr.
Automatic Private Branch Exchange Development in San Francisco.* Gerald Deakin. (42) Apr.
Electrification of a Reversing Mill of the Algoma Steel Co.* Bradley T. McCormick. (42) Apr.

*Illustrated.

Electrical—(Continued).

Self Starting Synchronous Motors. Carl J. Fechheimer. (42) Apr.
Central Station Practice in the Anthracite Coal Fields.* (62) Apr. 1.
Wires for Direct-Current Circuits. Cecil P. Poole. (64) Apr. 2.
Elektrische Temperaturmessung und Fernablesung unter besonderer Berücksichtigung des thermoelektrischen Verfahrens.* Alfred Schwartz. (48) Serial beginning Feb. 10.
Das vereinfachte elektrische Stellwerk.* Niemann. (48) Feb. 17.
Versuche an einer elektrisch betriebenen Hauptschachtförderanlage mit Schwungradausgleich.* H. Wille. (48) Mar. 2.

Marine.

Motors for Lifeboats.* (12) Mar. 1.
Internal-Combustion Engines for German Fishing-Boats.* F. Romberg. (Abstract of translation of paper read before the Schiffbautechnische Gesellschaft.) (11) Mar. 1.
The Sulzer Diesel Engines.* (11) Mar. 8.
The Marine Oil Engine. (11) Mar. 8.
The Twin Screw Motor Ship *Selandia*.* (12) Serial beginning Mar. 8.
The Dry-Dock at Ashtabula, Ohio.* E. C. Bowen, Jr. (13) Mar. 14.
The Ocean-Going Oil-Engined Ship *Sembilan*.* (11) Mar. 15.
An Analysis of the Claims of the Marine Internal Combustion Engine.* (12) Mar. 15.
The *Maine* Raised.* (14) Mar. 16.
Parsons' Steam-Turbines for an 18-Knot Ocean Liner.* (11) Mar. 22.
Success of the First Large Diesel Motor-Driven Liner.* J. Rendell Wilson. (95) Apr.
The United States Turbine-Driven, Naval Collier *Neptune*.* (95) Apr.
Sea-Going Producer Gas-Driven Cargo Vessel *Holzapfel I*.* F. C. Coleman. (95) Apr.
Projets d'Enlèvement de l'Epave du Cuirassé *Liberté*.* René Sabines. (33) Mar. 16.

Mechanical.

Electric Welding in Railway Shops.* O. S. Beyer, Jr. (25) Feb.; (65) Mar.
60-Foot Drop Testing Machine.* Andrew Lauterbach. (25) Feb.
The Vulcan Flexible System of Staying for Lancashire Boilers.* (94) Mar.
Notes on the Design of Cylindrical Tanks and Boilers.* F. A. Garrett. (94) Mar.
Hydrated Lime, and Tests Showing the Comparative Strength of Different Kinds of Lime Mortars.* W. B. Joseph. (36) Mar.
A Late Mechanical Engineering Laboratory.* Ellsworth Tonkin. (20) Mar. 7.
The Bituminous Gas Engine in South Africa.* (12) Mar. 8.
An Electrically-Operated Briquetting Plant.* (26) Mar. 8.
Testing the Power Requirements of Rolling Mills.* B. N. Westcott. (From *General Electric Review*.) (22) Mar. 8; (47) Mar. 8.
The Gas Turbine.* Norman Davey. (12) Serial beginning Mar. 8.
A Theoretical and Experimental Study of Mediate Friction. N. Petroff. (Translated from the French by P. H. Parr.) (12) Serial beginning Mar. 8.
Mixing and Melting: Notes on Foundry Practice With Cupola, Converter, Crucible and Open Hearth. David McLain. (Abstract from paper read before the Pittsburgh Foundrymen's Assoc. and Associated Foundry Foremen.) (62) Mar. 11; (20) Mar. 14.
Recent Improvements in Producer Gas Appliances.* Walter O. Amsler. (62) Mar. 11.
The Development of a By-Product Coke Oven Gas Plant.* Warren S. Blauvelt. (Paper read before the Am. Gas Inst.) (24) Mar. 11.
Hazard Mfg. Co.'s New Power Plant.* Warren O. Rogers. (64) Mar. 12.
Electric Rolling Mills at Middlesbrough.* (12) Mar. 15.
Recent Developments in the Manufacture of Water Gas. Viggo E. Bird. (Paper read before the New England Assoc. of Gas Engrs.) (83) Serial beginning Mar. 15; (24) Apr. 1.
Aeroplane Under-Carriages. G. de Haviland. (Paper read before the Inst. of Automobile Engrs.) (11) Mar. 15.
A Westinghouse Installation at Bahia Blanca.* (73) Mar. 15.
The Deutsch Aero-Dynamic Institute, Paris.* (19) Mar. 16.
Burning Shavings for Fuel at a Turbo-Generator Plant.* (14) Mar. 16.
Lohmannized Sheets; New Youngstown Company Puts Forth New Literature on Corrosion.* (62) Mar. 18; (101) Mar. 22; (20) Mar. 14.
Increasing the Capacity of Large Gas Engines.* F. E. Junge. (64) Mar. 19.
Gas-Furnace Work.* E. P. Taudevin. (Paper read before the Glasgow and West of Scotland Technical Inst.) (66) Mar. 19.

---

*Illustrated.

Mechanical—(Continued).

A Pump Delivering 50 Gal. per Min. at a Pressure of 5 000 Lb. per Sq. In.* (13) Mar. 21.

On the Wider Adoption and Standardization of Water-Tube Boilers.* E. M. Speakman. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning Mar. 22.

Steam Regenerative Accumulators.* D. B. Morison. (Abstract of paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (22) Mar. 22.

The Boland Tail-less Biplane.* (From *Aeronautics.*) (19) Mar. 23.

The Sand-Blending Plant at the Arrowrock Dam, Idaho. (14) Mar. 23.

Shaving Scrubbers. (For Gas Purification.) J. F. Wing. (Paper read before the New England Assoc. of Gas Engrs.) (24) Serial beginning Mar. 18; (83) Mar. 25.

The Centrifugal Compressor in the Manufacture of Gas.* L. C. Loewenstein. (Paper read before the Am. Gas Inst.) (24) Mar. 25.

Data on the Removal of Tar from Water Gas. A. P. Beardsley (Paper read before the New England Assoc. of Gas Engrs.) (24) Serial beginning Mar. 25; (83) Mar. 15.

Combination Power and Ice Plant.* Paul C. Percy. (64) Mar. 26.

Plant of the Portsmouth Steel Company.* (20) Mar. 28.

Oil Burning in Boiler Furnaces. E. W. Kerr. (Abstract from *Bulletin,* Louisiana State Univ.) (13) Mar. 28.

Cost of Isolated Plant Power.* American Engine Co. (96) Mar. 28; (64) Apr. 2.

A New Mill for Rolling Hard Steel Bars.* (20) Mar. 28.

The Suspended Passenger Cableway up Mont Blanc.* Francis P. Mann. (14) Mar. 30.

Motor Trucks in the Washington Sewer Department. (14) Mar. 30.

The Design of Model Propellers and Elastic Motors.* (For Airships.) E. A. Vessey. (19) Mar. 30.

The Work Done and the Power Required in Rolling Steel.* Harold Wheatley. (9) Apr.

High Pressure Distribution. C. G. Goeltz. (Paper read before the New England Assoc. of Gas Engrs.) (83) Apr. 1.

Industrial Gas Appliances.* H. L. Barnes. (Paper read before the New England Assoc. of Gas Engrs.) (83) Apr. 1.

Submerged Gas Mains at New Haven. H. E. White. (Paper read before the New England Assoc. of Gas Engrs.) (83) Apr. 1.

Tar and Tar Products.* Whittaker. (Paper read before the Am. Gas Inst.) (24) Apr. 1.

Winding Engines of the Ashley Planes.* Warren O. Rogers. (64) Apr. 2.

Uniform Boiler Specifications. American Boiler Mfrs. Assoc. (64) Apr. 2.

Le Tension-Mêtre. Largier. (32) Dec.

Nouveau Procédé pour la Reproduction Instantanée des Calques sur Tous Papiers, Toiles, etc. H. Claude. (32) Dec.

Note sur le Calcul du Travail du Métal dans les Cables Métalliques.* Edgar Baticle. (43) Jan.

Perfectionnements dans la Fabrication du Ciment de Portland.* Henry Peters. (84) Serial beginning Feb.

Note sur le Chauffage à l'Aide de la Vapeur de Décharge des Machines Monocylindriques ou de la Vapeur Prise au Receiver de Machines Compound. Lecuir. (37) Feb. 29.

Fonctionnement des Pompes Centrifuges en Régime Variable, Calcul de l'Epuisement d'une Forme de Radoub.* L. Bergeron. (37) Feb. 29.

Sur un Enregistreur Photographique.* Henry Le Chatelier et Witold Broniewski. (93) Mar.

La Fabrication du Papier et de la Poudre d'Aluminium.* Leon Guillet. (93) Mar.

Le Concours de Pare-Boue de l'Automobile-Club de Seine-et-Oise (Versailles, 4 Février, 1912).* E. Bret. (33) Mar. 9.

Die neuen Turbinenregler von Briegleb, Hansen & Co. in Gotha.* Thoma. (48) Serial beginning Jan. 27.

Technische Untersuchungen im Undosa-Wellenbad der Internationalen Hygiene-Ausstellung zu Dresden 1911.* (48) Jan. 27.

Versuche mit Riemen besonderer Art.* Kammerer. (48) Feb. 10.

Versuche über die Druckänderungen in der Rohrleitung einer Francis-Turbinenanlage bei Belastungsänderungen.* A. Watzinger und Oscar Nissen. (48) Serial beginning Feb. 10.

Neue Kraftmesser.* Georg Wazau. (48) Feb. 17.

Prüfungsmachine von 3 000 t Druckkraft für Eisenkonstruktionsteile.* Ad. Seydel. (50) Mar. 7.

Das Anwärmen von Radreifen auf elektrischem Wege.* R. Börnecke. (50) Mar. 14.

---

*Illustrated.

Metallurgical.

Cyaniding Tailings in Colombia.* Ralph W. Perry. (16) Mar. 9.
Cyanide Regeneration. B. George Nicholl. (Abstract from *The Mining and Engineering Review.*) (103) Mar. 16.
Combination Methods for Smelter Assays. A. T. French. (Abstract from *Bulletin* of the Institution of Mining and Metallurgy.) (103) Mar. 16.
An Electrical Drier for Zinc Precipitate.* Donald F. Irvin. (103) Mar. 16.
The Practice in Blende Roasting.* E. Schütz. (16) Mar. 16.
Cyaniding Weathered Pyritic Tailing. Herbert R. Edmans. (16) Mar. 23.
Blast Desiccation by Calcium Chloride.* J. B. Van Brussel. (16) Mar. 23.
The Purisima Grande Mill, Pachuca. E. Girault. (Abstract from *Informes y Memorias* del Instituto Mexicano de Minas y Metalurgia.) (103) Mar. 23.
La Formation de l'Osmondite dans les Aciers Hypo-Eutectiques.* J. Calian. (93) Mar.
Essais de Production de la Fonte au Haut Fourneau Electrique, à Trollhättan (Suède).* (33) Mar. 16.
Ueber die Berechnung des zur direkten Reduktion im Hochofen verbrauchten Kohlenstoffs. F. Wüst. (50) Mar. 7.
Ueber das Umschmelzen von Ferromangan im elektrischen Ofen.* R. Korten. (50) Mar. 14.

Military.

The Utilization of Electricity in United States Coast Defense.* L. B. Bender. (27) Mar. 30.

Mining.

Notes on the Valuation of Mineral Properties. T. A. O'Donahue. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) (106) Vol. 43, Pt. 1.
Testing for Fire-Damp and Black-Damp by Means of a Safety-Lamp.* Henry Briggs. (Paper read before the Min. Inst. of Scotland.) (106) Vol. 43, Pt. 1.
Miners' Baths.* H. F. Bulman and W. B. Wilson. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) (106) Vol. 43, Pt. 1.
Peckfield Colliery.* (22) Mar. 1.
Electric Haulages in Mines.* W. C. Mountain, M. I. E. E. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) Mar. 1.
Electric Winding on the Rand.* (26) Mar. 8.
A Method of Showing Ore Reserves.* N. H. Emmons, 2d. (16) Mar. 9.
Methods of Restoring Soil on Dredged Areas and Costs of Gold Dredging in Australia. (86) Mar. 13.
The Estimation of Firedamp in Mines.* F. K. Cartwright. (Paper read before the National Assoc. of Colliery Mgrs.) (57) Mar. 15.
Maltby Main Colliery. (22) Mar. 15.
Electricity Applied to the Scottish Shale Oil Industry.* Jas. R. Laird. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) Mar. 15.
Preliminary Handling of Ore at El Tigres.* J. W. Malcolmson and L. R. Budrow. (103) Mar. 16.
Progress in Mill Design (Ore crushing). Frank E. Shepard. (16) Mar. 16.
Argentine Government Aërial Tram.* (For Mines.) C. A. Tupper. (16) Mar. 23.
Flume Construction in Colombia.* R. D. O. Johnson (16) Mar. 30.
Mining and Concentrating the Sydvaranger Iron Ores.* Dwight E. Woodbridge. (9) Apr.

Miscellaneous.

Graphic Determination of Pressures on Retaining Walls.* J. A. Main (12) Mar. 1.
Engineering Photography.* Lyman B. Jackes. (96) Mar. 7.
Some Modern Problems of Illumination.* T. Thorne Baker. (29) Mar. 8.
A Code of Ethics and Schedule of Fees for Consulting Engineers. (13) Mar. 14.
New Paper Specifications for the Government Printing Office. (13) Mar. 14.
The Weight and Expansion of Excavated Earth. (13) Mar. 21.
A Congressional Investigation of Scientific Management. (13) Mar. 28.
Les Rayons Ultra-Violets et Leurs Pratiques.* Daniel Berthelot. (32) Dec.

Municipal.

The Chemistry of Modern Highway Engineering. Prevost Hubbard. (Paper read before the Am. Assoc. for the Advancement of Science.) (104) Mar. 8.
Motor Trucks for Road Oiling. (14) Mar. 9.
Nozzle for Spraying Bitumens on Macadam Roads.* (14) Mar. 9.
Methods and Costs of Constructing a Stone-Gravel Road on a Sand Sub-Grade in Menominee County, Michigan.* K. I. Sawyer. (86) Mar. 13.
An Improved Distributor for Heavy Road Binders.* (13) Mar. 14.

---

*Illustrated.

Municipal—(Continued).

Good Roads and How to Build Them.* Logan Waller Page. (46) Mar. 16.
The Coleman du Pont Highway Through the State of Delaware.* Coleman du Pont. (46) Mar. 16.
Characteristics and Costs of Standard Types of Street Pavements, Data from a Report of a Comprehensive Plan for Developing the Streets of Cambridge, Massachusetts. (14) Mar. 16.
Preventing Dust on Macadam Streets. John F. Icke. (Abstract of paper read before the Eng. Soc. of Wis.) (14) Mar. 16.
Proper Methods of Recording, Interpreting and Estimating Road and Pavement Maintenance Costs. (86) Mar. 20.
Cost of Operating a Steam Road Roller on Macadam Pavement Work. E. W. Robinson. (86) Mar. 20.
Hearing at Boston on Motor-Truck Limitation Bill. (14) Mar. 23.
Methods of Staking out Paving Work. Delay. (Abstract of paper read before the Iowa Eng. Soc.) (14) Mar. 23.
Cost Data on Hauling Stone with a 22-Horse Power Traction Engine and Stone Spreading Cars, Gatcheville Road, York County, Pennsylvania.* John F. Hammond. (86) Mar. 27.
The State Administration of Public Highways in the United States. (13) Mar. 28.
A Machine for Cutting Granite Cubes for Paving. (13) Mar. 28.

Railroads.

The Detroit River Tunnel.* Wilson Sherman Kinnear, M. Am. Soc. C. E. (54) Vol. 74.
Pioneer Railway Development in the United States.* W. D. Taylor, M. Am. Soc. C. E. (54) Vol. 74.
Balanced Compound 4-6-2 Locomotives.* (25) Feb.
Repair Shop Improvements at Buffalo.* C. C. Leech. (25) Feb.
Effect of Firebox Volume on Combustion.* F. F. Gaines. (25) Feb.
Steel Wheels.* Chas. G. Bacon, Jr. (61) Feb. 20.
Fish-Belly Center Girders for Cars.* Arthur E. Heffelfinger. (15) Mar.
100-Ton, 36-ft., Flat Car, Pittsburgh & Lake Erie.* (25) Mar.
Mikado Locomotives of Great Power.* (25) Mar.
Pacific Type Locomotives, Nashville, Chattanooga & St. Louis.* (25) Mar.
Long Island All Steel Parlor Cars.* (25) Mar.
The Indicative Arrangement and Location of Railway Signals.* J. F. Gairns. (88) Mar.
The Regular Running of Goods Trains on Steep Gradients.* A. Huberti and J. Doyen. (88) Mar.
Concrete Practice, Typical and Standard Structures of the Chicago, Milwaukee & St. Paul Ry.* (87) Serial beginning Mar.
Rio Puerco Grade Revision, A., T. & S. F. Ry.* J. G. Van Zandt. (87) Mar.
Tie Treating Plant at Albuquerque, N. M.* C. W. Wiggett. (From *Santa Fe Employes' Magazine.*) (87) Mar.
Tap-Feed (Locomotive) Great Western Railway.* (21) Mar.
The A. B. C. Automatic Buffer Coupler.* (21) Mar.
4-6-0 Express Passenger Engine No. 1 500, Great Eastern Railway.* (21) Mar.
Petrol-Driven Inspection Car; North Eastern Railway.* (21) Mar.
Single-Phase Locomotive with Continuous-Current Rectifiers. A. Soulier. (Abstract from *L'Industrie Electrique.*) (73) Mar. 1.
Two New Electric Locomotives.* (18) Mar. 9.
Recent Developments in Car Heating and Ventilation. Lewis C. Ord. (Abstract of paper read before the Canadian Ry. Club.) (18) Mar. 9.
New Indianapolis Power Station.* (17) Mar. 9.
A Study of Rail Failures. D. F. Jurgenson. (Abstract of paper read before the Minn. Surveyors and Engrs.' Soc.) (14) Mar. 9.
The Construction of Railroad Track Scales: A Review.* (62) Mar. 11.
Special Design for Retaining Wall.* (15) Mar. 15.
Automobile Car for the Chicago, Milwaukee & St. Paul.* (15) Mar. 15.
Construction Work on the Grand Trunk Pacific Ry.* (18) Mar. 16.
Leakage in Subaqueous Tunnels. (14) Mar. 16.
A One Hundred-Ton Mexican Wrecking Crane.* (19) Mar. 16.
Notes on Contract Ballasting, Missouri Pacific Ry., Including Tables for Calculating Volume of Ballast Applied; Also Cost and Progress Recording Forms Used.* D. W. Stradling. (86) Mar. 20.
New Superheater Tank Engines, North Staffordshire Railway.* (12) Mar. 22.
The Construction of the Oregon Trunk and the Des Chutes Railways in Central Oregon.* (15) Mar. 22.
The Bernina Railway.* Alfred Gradenwitz. (19) Mar. 23.
An Analysis of Rail Failures From a Year's Statistics. (14) Mar. 23.
Rack Railway Tracks; Panama Locks.* (62) Mar. 25.
A Gravel Washing Plant for Railway Ballast; Structural Details and Methods and Cost of Operation.* (86) Mar. 27.

---

*Illustrated.

Railroads—(Continued).

The Development of the Railway Rail in the United States.* (86) Mar. 27.
Balanced-Compound Locomotives (A., T. & S. F. Ry.).* (13) Mar. 28.
Construction of the Bingham & Garfield R. R.* (15) Mar. 29.
Santa Fe Dynamometer Car.* H. B. MacFarland. (15) Mar. 29.
A Three-Story Water Tank. (B. & O. R. R.) (14) Mar. 30.
New Steel Cars for the New York, Westchester & Boston Railway.* (17) Mar. 30.
Piercing the Jungfrau Tunnel.* Alfred Gradenwitz. (46) Mar. 30.
The Package-Handling System of the New American Express Terminal, New York. (14) Mar. 30.
Railroad Construction in China.* (14) Mar. 30.
All Steel Box Cars, Bessemer & Lake Erie R. R.* (18) Mar. 30; (15) Mar. 22.
Carson-Burgess Cab Signal and Automatic Train Stop.* (18) Mar. 30.
Electric Locomotive for 1 500 Volts, Direct Current.* (18) Mar. 30.
Considérations sur la Forme à Donner aux Coussinets de Boîtes à Huile et de Bielles de Locomotives.* A. Berger et A. Laviolette. (31) Vol. 4, Pt. 4.
Locomotive type Pacific à Quatre Cylindres à Admission Directe, Compagnie des Chemins de Fer de Paris à Lyon et à la Méditerranée.* (34) Mar.
Note sur les Voitures de Banlieue et les Wagons à Bagages à Guérite Intérieure Centrale de la Compagnie Paris-Lyon-Méditerranée.* Lancrenon. (38) Mar.
Nouveaux Freins à Main, Système Mestre des Chemins de Fer de l'Est.* (33) Mar. 2.
Les Avaries des Plaques Tubulaires dans les Chaudières de Locomotives.* H. Lavialle d'Anglards. (33) Mar. 9.
Zur Erforschung der Lokomotivüberhitzer.* Lomonossoff und Tschetschott. (48) Feb. 3.
Neuer Endbahnhof der New York-Central-Eisenbahn in der City von New York.* (51) Feb. 28.
Wagen-Reinigungs- und Entseuchungs-Anstalten. Fr. Mayscheider. (102) Mar. 1.
Aufgleiser für entgleiste Eisenbahnfahrzeuge von Podolsky und Strauss.* W. Murai. (102) Mar. 1.
Die Berechnung der Hauptabmessungen von Druckluft-lokomotiven.* Rud. Engel. (48) Mar. 2.
Der Kraftbedarf der Gotthardbahn mit Rücksicht auf die Neuanlagen für deren elektrischen Betrieb.* W. Kummer. (107) Serial beginning Mar. 9.
Die neuen elektrischen Lokomotiven der Berner Alpenbahn.* (107) Mar. 16.

Railroads, Street.

Railless Trolley Cars.* (96) Mar. 7.
The Trolley Vehicle System of Railless Traction. Henry C. Adams, Assoc. M. Inst. C. E. (Paper read before the Soc. of Engrs.) (104) Mar. 8; (22) Mar. 8.
Shield for Tunnelling Work at Baker Street Station.* (11) Mar. 8.
New Center-Entrance Car in New York.* (17) Mar. 16.
Ozonized Air in the London Subway. (14) Mar. 23.
New Shops and Carhouses of the Boston Elevated Railway in Cambridge, Mass.* (17) Mar. 23.
New Power Station of Boston Elevated Railway Company.* (27) Mar. 23.
All-Steel Center-Entrance Car for Brooklyn.* (17) Mar. 30.

Sanitation.

Reinforced Concrete Pipe Construction for Regina Sewer. W. R. Harris. (67) Mar.
Sewage Sludge and Its Disposal. J. Grossmann. (Paper read before the Soc. of Chemical Industry.) (104) Mar. 1.
The Chemical Principles Involved in Sewage Disposal. George C. Nassmith. (Paper read before the Canadian Public Health Assoc.) (96) Mar. 7.
Stability of Effluents from Contact and Trickling Filters. (14) Mar. 9.
The Salt Lake Outlet Sewer.* (14) Mar. 9.
A Review of the Methods of Disposal of Municipal Refuse Progress of the Art—Data of Operation of Cleveland and Buffalo Plants. (86) Mar. 13.
The Relation of the Putrescibility of the Settling and Non-Settling Suspended Matter in Sewage. Arthur Lederer. (Paper read before the Am. Public Health Assoc.) (96) Mar. 14.
Bacterial Contents of Allegheny, Monongahela and Ohio Rivers at and below Pittsburg. (13) Mar. 14.
Sewage Purification at Atlanta.* Wm. A. Hansell, Jr. (13) Mar. 14.
A Centrifugal Pump for Unscreened Sewage.* (13) Mar. 14.
Ventilation of Office Buildings.* Charles L. Hubbard. (101) Serial beginning Mar. 15.
Sewage Works and Street Gullies as Breeding Grounds of Mosquitoes.* Elwin H. T. Nash. (104) Mar. 15.
Evanston's Experience with Hypochlorite of Lime and Typhoid Fever, a Summary of Results of Sterlizing Lake Michigan Water. W. Lee Lewis. (14) Mar. 16.

*Illustrated.

Sanitation—(Continued).

Enclosing a Sewage-Laden Stream in a Triple-Barrel Concrete Conduit; Concrete for the Jones' Falls Improvement at Baltimore was Distributed from Hoppers at the Tops of Tall Wooden Towers.* (14) Mar. 16.
Methods of Garbage Collection in Milwaukee, Present and Proposed: The Estimated Saving in Cost Under New Method. Robert E. Goodell. (86) Mar. 20.
Electrolytic Sewage Treatment.* Howard V. Hinckley. (13) Mar. 21.
Typhoid Outbreak, Cedar Falls, Iowa.* A. L. Grover and R. B. Dole. (13) Mar. 21.
Piney Branch Trunk Sewer Outlet, Rock Creek Park, Washington, Decorative Treatment of an Outfall to Which Flow of Sewage is Regulated Automatically.* (14) Mar. 23.
Drainage Power Plant at New Orleans.* Cecil P. Poole. (64) Mar. 26.
An Economic Study of the Four Alternate Methods Considered for the Disposal of the Garbage, Rubbish and Ashes of Toronto. Hering and Gregory. (86) Serial beginning Mar. 27.
Cleveland Intercepting Sewer System.* J. M. Estep. (13) Mar. 28.
City Waste Studies in Ohio Cities. (13) Mar. 28; (14) Mar. 23.
Zerstörung von Beton durch Bodenbestandteile. (Sewer Pipes.) Ernst Schick. (80) Feb. 29.

Structural.

Some of the Properties of Oil-Mixed Portland Cement Mortar and Concrete.* Logan Waller Page, M. Am. Soc. C. E. (54) Vol. 74.
Economy in Rectangular Panels, Using Beams of Constant Cross-Section.* J. S. Branne, Assoc. M. Am. Soc. C. E. (54) Vol. 74.
Retrogression in the Tensile Strength of Cement.* J. M. O'Hara, Assoc. M. Am. Soc. C. E. (54) Vol. 74.
Report on Five Samples of Magnetic Sheet Material Tested for Total Loss and Hysteresis at the Physikalisch-Technische Reichsanstalt, the Bureau of Standards, and the National Physical Laboratory. Albert Campbell, H. C. H. Booth and D. W. Dye. (77) Feb.
Protective Coatings. Walther Riddle. (58) Feb.
Historic Notes on Metallic Beams and Girders.* R. B. Woodworth. (58) Feb.
Comparative Tests of Cement Gun Concrete and Hand Applied Concrete.* (67) Mar.
Electrolytic Corrosion of Steel in Concrete.* (67) Mar.
Concrete Work on the Fourth Avenue Subway. Samuel M. Purdy, M. Am. Soc. C. E. (36) Mar.
Finishing Concrete Surfaces. Jerome Cochran. (36) Mar.
Hydrated Lime and Tests Showing the Comparative Strength of Different Kinds of Lime Mortars.* W. B. Joseph. (36) Mar.
The Berlin Technical High School at Charlottenburg.* H. S. Rowell. (11) Serial beginning Mar. 8.
The New Electrotechnical Laboratories of the University of Manchester.* (73) Mar. 8.
Properties of Hand-Mixed and Cement-Gun Mortars. (14) Mar. 9.
Tests of a Reinforced Concrete Flat Slab Building Floor to Determine Actual Stresses. W. K. Hatt. (Paper read before the Indiana Eng. Soc.) (86) Mar. 13.
Tests on the Strength of Nailed Joints.* J. H. Thornley. (From *Applied Science.*) (96) Mar. 14.
Wrought Iron, Steel and Corrosion.* William R. Fleming. (20) Mar. 14.
Five-Year Tests on Cement Briquettes, Showing Decrease in Tensile Strength.* C. A. Morse. (13) Mar. 14.
The Scantlings of Reinforced Concrete Piles.* Frank H. Jeffrey, A. M. Inst. C. E. (11) Mar. 15.
Eliminating Columns by a Heavy Girder.* (14) Mar. 16.
Steam Tests on Concrete and Mortar. (14) Mar. 16.
Making Concrete Pipe at Temperatures Below Zero. (14) Mar. 16.
Shoring and Remodeling the Front of a New York Building.* (14) Mar. 16.
Lohmannized Sheets; New Youngstown Company Puts Forth New Literature on Corrosion.* (62) Mar. 18; (101) Mar. 22; (20) Mar. 14.
Approximate Design in Structural Steelwork. George A. Merrill. (13) Mar. 21.
Tables for the Strength of One-Line Rivet Connections Under Eccentric Load.* E. L. Wood. (13) Mar. 21.
Diagram for Determining the Pitch of Rivets in Plate Girders.* Edward C. Dilworth. (13) Mar. 21.
Some Notes on Column Designs.* F. Tissington. (96) Mar. 21.
Difficult Floor Renewal in a Tannery, Driving 25-foot Piles Where the Headway was Limited to 16 Feet.* (14) Mar. 23.
Shearing Stresses in Concrete Steel Beams.* Hector R. Burroughs, Assoc. M. Am. Soc. C. E. (14) Mar. 23.

*Illustrated.

Structural—(Continued).

Concrete Building with Composite Column Foundations.* (14) Mar. 23.
The Practical Design of Reinforced Concrete Flat Slabs.* Sanford E. Thompson. (Paper read before the National Assoc. of Cement Users.) (96) Serial beginning Mar. 28.
Unit Costs of Reinforced Concrete for Industrial Buildings. Chester S. Allen. (Paper read before the National Assoc. of Cement Users.) (96) Mar. 28; (86) Mar. 27.
The Storage of Portland Cement.* (96) Mar. 28.
Field Compression Tests of Concrete. G. H. Bayles. (13) Mar. 28.
Steelwork in Hotel McAlpin, New York, Deep Girders with Double and Triple Webs in Foundation and Superstructure.* (14) Mar. 30.
Note sur le Calcul des Poutres en Béton Armé.* Hachon. (43) Jan.
Application du Béton fretté à la Fonte.* (84) Feb.
Les Altérations du Mortier de Ciment dans l'Eau de Mer. (84) Feb.
Abaques Relatifs à la Recherche du Profil des Voutes en Plein Cintre ou en Arc de Cercle.* A. Pirot. (30) Feb.
Déplacement du Mur de Cloture de la Gare des "Mille Wagons" à la Porte du Schyn, à Anvers.* J. Bouvart et Paul Deheem. (30) Feb.
Le Monument de Victor-Emmanuel II à Rome.* Francesco Pollastri. (33) Mar. 16.
Die Kleinstwerte für Balken, Unterzüge und Geländer.* Wilcke. (81) Pt. 2
Einfluss der Formänderung auf die Kräfte im statisch bestimmten Fachwerk.* Gaber. (81) Pt. 2.
Neue Versuche mit ringbewehrten Säulen.* A. Kleinlogel. (51) Serial beginning Sup. No. 5.
Versuche mit Flanschenverbindungen.* R. Baumann. (48) Feb. 3.
Versuche über die Elastizität und Festigkeit von Bambus, Akazien-, Eschen- und Hickoryholz.* R. Baumann. (48) Feb. 10.
Versuche über die Verdrehung von Stäben mit rechteckigem Querschnitt und zur Ermittelung der Längs- und Querdehnung auf Zug beanspruchter Stäbe.* O. Bretschneider. (48) Feb. 17.
Zur Berechnung der Boden- und Seitendrücke in Silos auf Grund der Versuche von T. Bienert. A. S. Oesterreicher. (48) Feb. 24.
Kaminschwankungen.* N. Peters. (80) Feb. 29.
Dresdens neuer städtischer Vieh- und Schlachthof.* (48) Serial beginning Mar. 2.
Biegungsversuche an gusseisernen Stäben.* R. Schöttler. (48) Serial beginning Mar. 2.
Das kleine Krankenhaus.* Max Setz. (53) Serial beginning Mar. 8.
Beitrag zur Berechnung von einfach bewehrten Platten.* Gustav Lichtenstein. (78) Mar. 11.
Der konstruktive Aufbau der Lutherkirche zu Worms a. Rh.* (78) Mar. 11.
Abnutzbarkeit von Zement und Zementmörtel.* H. Burchartz. (80) Mar. 23.

Topographical.

La Photographie et la Photogrammétrie, Applications aux Levés des Pays de Montagnes.* Paul Helbronner. (33) Mar. 9.

Water Supply.

Two Earth Dams of the United States Reclamation Service.* D. C. Henny, M. Am. Soc. C. E. (54) Vol. 74.
The Flow of Water in Cylindrical Conduits.* Sidney A. Reeve. (54) Vol. 74.
The Present-Day Pumping Engine for Water-Works.* Charles Arthur Hague, M. Am. Soc. C. E. (54) Vol. 74.
A Reinforced Concrete Stand-Pipe.* W. W. Clifford, Jun. Am. Soc. C. E. (54) Vol. 74.
Experiments on the Flow of Water in Wood Stave Pipes.* E. A. Moritz, Assoc. M. Am. Soc. C. E. (54) Vol. 74.
Flow Through Triangular Notches or Weirs.* Ralph B. Dandt. (36) Mar.
Wooden Pipes and Pipe Covering.* (87) Mar.
The Hydro-Electric Power Scheme of the City of Winnipeg.* (73) Serial beginning Mar. 1.
The Ocoee River Power Development.* J. A. Switzer. (96) Mar. 7.
Preventing Leakage from the Washington Aqueduct at Cabin John Bridge.* (14) Mar. 9.
Accident at the Pathfinder Dam. (14) Mar. 9.
New Roller Headgates at the McCall Ferry Plant.* (14) Mar. 9.
The Rapid Mechanical Filtration Plant of the Montreal Water and Power Company; the Compressed Air and Water Used for Washing the Filters will be Stored in a Telescopic Tank Similar in Design to a Gasholder.* (14) Mar. 9.
The Oak Knob Concrete Reservoir at Harrisburg. (14) Mar. 9.

*Illustrated.

Water Supply—(Continued).

Two New 18 000 000-Gallon Units in New York's 98th Street Pumping Station.* F. E. Walker. (14) Mar. 9; (64) Mar. 12.
Chart for Solution of Problems in Irrigating Waters.* H. C. Ogden. (14) Mar. 9.
Acid and Iron from Mine Wastes. (Effect on Water Supplies.) (14) Mar. 9.
Hydro-Electric Irrigation Project.* H. B. McDermid. (64) Mar. 12.
General Methods of Difficult Cofferdam Construction at Koochiching Falls Power Development, Minnesota.* H. C. Ash, M. Am. Soc. C. E. (Paper read before the Minnesota Surveyors and Engrs.' Soc.) (86) Mar. 13.
The Water Resources of Minnesota, Storage Development Planned and Under Way.* (86) Mar. 13.
Cost of Water Purification. (96) Mar. 14.
Geology of Dam Trenches.* Herbert Lapworth. (13) Mar. 14.
Water Measurement and Prevention of Water Waste, New York City.* (13) Mar. 14.
Water-Waste Surveys at Milwaukee, Wis. (13) Mar. 14.
Mechanical Water Softener.* (19) Mar. 16.
Hydroelectric Station of the Cia Docas de Santos, Brazil.* (27) Mar. 16.
Evanston's Experience with Hypochlorite of Lime and Typhoid Fever, a Summary of Results of Sterilizing Lake Michigan Water. W. Lee Lewis. (14) Mar. 16.
Incrustations of Filter Sands. (From *Journal, Industrial and Engineering Chemistry.*) (14) Mar. 16.
The Marshall Hydroelectric Plant on the French Broad River.* N. Buckner. (14) Mar. 16.
Hydraulic Stripping for Dam Foundation. (14) Mar. 16.
An Irrigation Project on the Medina River, Texas. (14) Mar. 16.
Water Department Methods. (14) Mar. 16.
The Value of Pure Water. Charles B. Burdick. (Abstract of paper read before the Ind. San. and W. S. Assoc.) (14) Mar. 16.
Use of Reinforced Concrete in the Hypochlorite Water Sterilization Plant at Kansas City, Mo.* (86) Mar. 20.
Pitometer Survey of Water Mains.* (96) Mar. 21.
A Method for Computing the Size of a Spillway for a Dam.* H. K. Palmer. (13) Mar. 21.
High Dams of Great Length.* Reginald Ryves, Assoc. M. Inst. C. E. (Paper read before the Concrete Inst.) (104) Mar. 22.
St. Petersburg's Water Sterilizing Plant, Suppressing Typhus and Cholera Epidemics with Ozone.* C. Van Langendonck. (46) Mar. 23.
Thawing 6-in. Water Main Under East River, New York.* (27) Mar. 23.
Operating Results at the Steelton Filters. (14) Mar. 23.
Small Things in the Operation of a Pumping Station. M. M. Symons. (Abstract of paper read before the Ill. Water Supply Assoc.) (14) Mar. 23.
The Canadian Pacific Railway Company's Irrigation Project in Alberta; a Composite Dam with Earth Body and Concrete Spillway Section of the Deck and Buttress Type will Divert Water from the Bow River.* (14) Mar. 23.
The Design of the Evanston, Ill., Hypochlorite Plant: The Decrease in Typhoid Fever Cases Following Installation of Plant.* C. C. Sauer. (86) Mar. 27.
Procedure Followed in Public Drainage Ditch Work in Southern Minnesota with General Costs of Ditch Work.* C. W. Gove. (Paper read before the Minnesota Surveyors and Engrs.' Soc.) (86) Mar. 27
Description of the Prosser Division of the Sunnyside Unit, Yakima Project, United States Reclamation Service.* (13) Mar. 28.
The Cableway Accident at the Pathfinder Dam.* (13) Mar. 28.
Concentration of Water Power Control. (13) Mar. 28.
Power Development at Sandy Falls on the Mattagami River.* (14) Mar. 30.
Disinfecting Lake Water with Calcium Hypochlorite. (14) Mar. 30.
The Condition of Old Mechanical Filters, Report Upon the Plant at Quincy, Illinois, Which Has Been in Service 20 Years. (14) Mar. 30.
An Equalizer Reservoir on a Gravity Flow Line.* (14) Mar 30.
Motor Trucks for Hauling Blasted Rock from City Aqueduct Tunnel, New York.* (14) Mar. 30.
Selection of a Water Wheel Unit.* O. B. Coldwell. (42) Apr.
Irrigation in the Spokane Valley.* L. J. Corbett. (42) Apr.
Note sur un Siphon d'Adduction d'Eau Potable.* Minguier. (43) Jan.
Alimentation du Canal d'Orléans par Elévation de l'Eau de Bief en Bief. Rousseau. (43) Jan.
Sur Quelques Formules Inexactes de l'Hydraulique.* D. Banki. (37) Feb. 29.
Barrage de Grünwald, près Gablonz (Bohême). (From *Allgemeine Bauzeitung.*) (35) Serial beginning Mar.
Die Rohrfrage auf der Internationalen Hygieneausstellung in Dresden und in der Praxis.* G. Blanchart. (50) Feb. 29.
Siegwart-Röhren.* (78) Mar. 11.

*Illustrated.

Waterways.

Economic Canal Location in Uniform Countries.* Lyman E. Bishop, Jun. Am. Soc. C. E. **(54)** Vol. 74.

A Concrete and Steel Ore Dock Having New Features in its Design. Rapid Ore Handling Sought in Great Northern Railway's Dock at Allouez Bay.* W. E. King. **(14)** Mar. 9.

Pumps and Motors for Panama Locks. **(62)** Mar. 11.

Canadian Northern Pacific Railway Company's Wharf at Port Mann, B. C.* W. G. Swan. **(96)** Mar. 14.

Breakwater at Svaneke, Island of Bornholm.* **(11)** Mar. 15.

Method and Cost of Constructing a Reinforced Concrete Retaining Wall with Rear Anchorage.* R. A. Boothe. **(86)** Mar. 20.

The Panama Canal Electric Towing Locomotives.* **(13)** Mar. 21.

Method of Constructing a Steel Sheet Pile Cofferdam in 37 Feet of Water for the Removal of the Battleship *Maine*.* **(86)** Mar. 27.

The Discretion of Government Engineers. (Decision on Work in San Francisco Harbor.) **(14)** Mar. 30.

Les Ouvrages Maritimes du Port de Rosyth.* **(84)** Feb.

Echafaudage Mobile, Système Piercy pour Travaux Maritimes.* Ch. Dantin. **(33)** Mar. 2.

Die Simmenkorrektion St. Stephan.* R. Meyer. **(107)** Mar. 9.

---

*Illustrated.

Vol. XXXVIII. APRIL, 1912. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

CONTENTS

PLATES

For Index to all Papers, the discussion of which is current in *Proceedings*, see the end of this number.

Vol. XXXVIII. APRIL, 1912. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A REINFORCED CONCRETE INFILTRATION WELL AND PUMPING PLANT.

By Frederick N. Hatch, Jun. Am. Soc. C. E.
To be Presented May 1st, 1912.

In this paper will be given a brief description of the design, equipment, and construction of a pumping station recently constructed for the Chesapeake and Ohio Railway at Silver Grove, Ky., as a part of the terminal improvements carried out by the company with which the writer is connected.

It was estimated that the ultimate quantity of water which would be required to supply the terminal would not exceed 1 000 000 gal. per 24 hours, and that the demand would be at a fairly uniform rate throughout that period. As the terminal is near the bank of the Ohio River, water was to be obtained from that stream and delivered to two 100 000-gal. tanks on towers 45 ft. high.

The Ohio River at this point is subject to an extreme variation of about 69 ft. between low and high stages, and it was necessary to design a plant which would operate satisfactorily at any stage. It was also desirable that the plant should be as nearly automatic in its operation as possible, as it would have to be about 700 ft. from the nearest shop building.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Test borings, made at several points on the river bank, showed that the top soil is underlaid by sand and gravel, and that the river bed is in the same formation. With this in mind, it was decided to sink a well on the bank and provide openings in it so that it would receive water by infiltration from the river through the intervening sand and gravel. It was expected that water obtained in this way would not contain much suspended earthy matter, though the Ohio is a turbid stream during high-water stages.

The sounding taken at the point at which the well was finally located showed the different strata to be as follows, the elevation given being that of the top of each stratum:

	Elevation.
Extreme high water in the river	407.3
Surface of ground, loam and sand	376.0
Loam and clay	361.0
Gravel, with some sand	354.0
Sand, with some gravel	343.0
Extreme low water in the river	338.1
Fine white sand	330.0
Bed-rock	291.0

The bottom floor was fixed at Elevation 328.0, or 10 ft. lower than extreme low water, and the motor floor is above the highest stage of water.

The pumping requirements and conditions are as follows:

Minimum capacity	700 gal. per min.
Maximum static head	127 ft.
Minimum " "	66 "
Discharge	through 1 000 ft. of 8-in. cast-iron pipe.

The pumps are to be driven by electric motors taking 3-phase, 60-cycle, 440-volt current; the motors are to be controlled automatically by the water level in the tanks; and all equipment is to be in duplicate.

Constant-speed, centrifugal pumps were selected on account of the great variation of effective head, and the fact that pumps of this type have a low starting torque, which is favorable to automatically-controlled, alternating-current, motor drive. The pumps are 5-in., constant-speed (1 140 rev. per min.), top-suction, vertical, single-stage, centrifugal turbines, manufactured by Henry R. Worthington. At low-

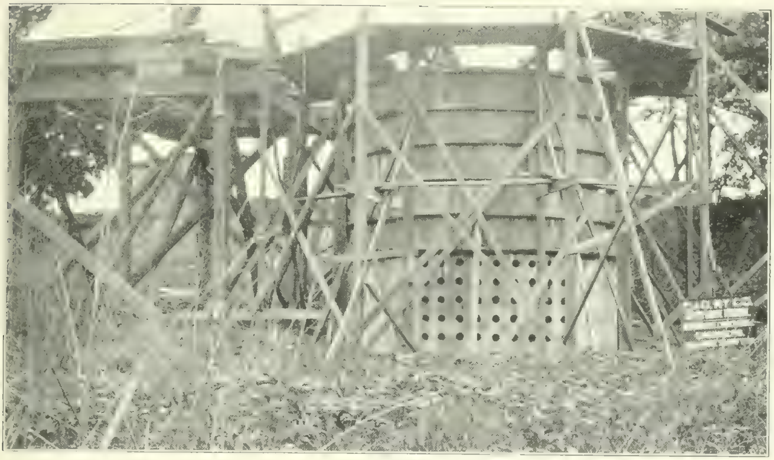


FIG. 1.—LOWER PART OF SHAFT BEFORE SINKING, SHOWING OPENINGS THROUGH WHICH WATER IS ADMITTED.

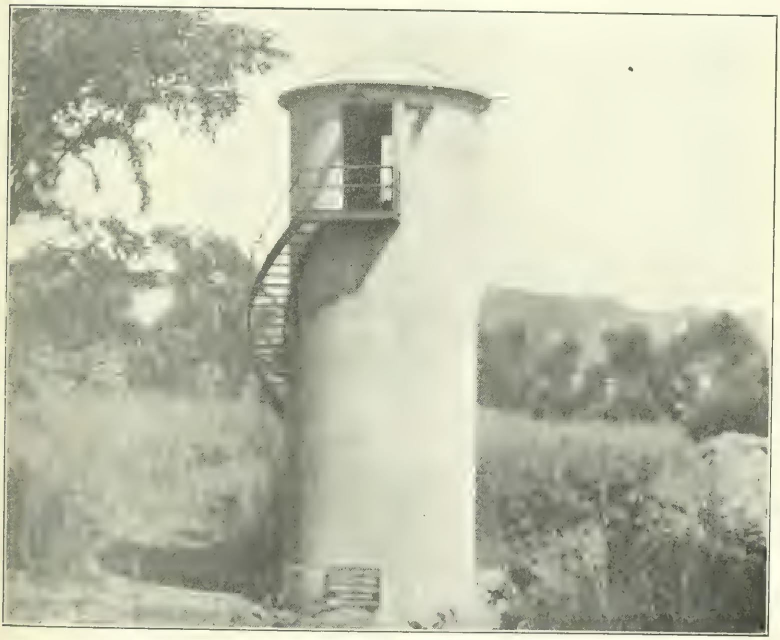


FIG. 2.—COMPLETED INFILTRATION WELL.

water stages each has a capacity of 700 gal. per min. against a total head of 142 ft., and requires 43.5 motor h.p. to operate it; at high water, against a total head of 104 ft., the discharge is 1 150 gal. per min., and the required horse-power is 50.5.

Each pump is driven by a Westinghouse 50-h.p. squirrel-cage type, induction motor, mounted on a cast-iron base on the motor-room floor. Each motor is controlled by a separate automatic starter, the two starters being mounted on one board and connected to the power line so that only one motor can be operated at a time. The solenoid switches of the starters are actuated by single-phase current controlled by a float-switch on one of the tanks. In order to prevent too frequent operation of the pumps, the float-switch is arranged so that it does not close until the water level has fallen to a point 5 ft. below the top of the tanks.

The shafts connecting the pumps to the motors are held in alignment by guide-bearings, adjustable in all directions, attached to rigid, built-up beams. The entire weight of the shaft and any possible unbalanced thrust of the pump impeller is carried by a marine-type thrust-bearing, mounted just below each motor. Flexible couplings prevent any of the weight of the main shaft from being transmitted to the motor rotor shaft and its separate thrust-bearing.

The entire shell of the well, including the motor-house and roof, is of reinforced concrete. The shell was designed to be sunk as an open caisson below the ground level. Sufficient reinforcement was provided to prevent the walls from pulling apart in case the upper part of the shaft should be held by the forms or the friction of the earth, while the lower part was free. Besides providing for the erection stresses, the walls and bottom were reinforced to withstand any possible unbalanced earth or water pressure.

The motor-room floor was designed for a live load of 400 lb. per sq. ft. plus the concentrated loads of the motors, shafts, etc.

Water is admitted to the well through 63 openings formed by pieces of 5-in., wrought-iron pipe extending through the walls of the well below the low-water line. The aggregate area of the openings is 8.75 sq. ft. These openings are shown on Fig. 1, Plate XXIX, the photograph having been taken just after the sinking of the shaft began. Inside the well these holes are enclosed by a steel-plate chamber designed to withstand the unbalanced hydraulic pressure on the inlet

side during high-water periods, with the inside of the shaft dry. A 24-in. sluice-gate, to control the inflow of water, is mounted on the side of this chamber. The gate is operated by a geared stand on the motor-room floor. To insure the proper spacing of the inlet chamber anchor-bolts, and also to provide an even joint surface, a steel angle companion flange was made with the flange of the chamber as a template. This companion flange was built into the concrete wall, and the anchor-bolts, which had enlarged ends tapped inside for 1-in. tap-bolts, were held in place by tap-bolts extending through the forms. A sheet-lead gasket was inserted between the companion flange and the flange of the chamber.

There is an opening, enclosed by a pipe railing, in the motor-room floor to give access to the lower part of the well, and steel ladders extend from bottom to top, inside.

The built-up beams for supporting the shaft guide bearings were designed for rigidity, and were set in pockets left in the walls of the well during construction. As the cover-plate serves as a walkway for inspecting the guide bearings, each beam has a pipe railing along one side of it.

A single I-beam, suspended above the motor-room floor and the hatchway, and extending as a cantilever beyond the entrance platform, serves as a track for a 4 000-lb. trolley provided to handle any of the heavy equipment.

An outside spiral steel stairway gives access to the head-house. The brackets supporting the stairway were built into pockets in the outside of the walls of the shaft.

The estimated weight of the well complete with its equipment is 530 tons, while the gross buoyancy during extreme high water, with no water inside the well, is about 465 tons, leaving a margin of stability of 65 tons, if the friction between the earth and the lower part of the shell is neglected.

Fig. 2, Plate XXIX, is a view of the completed well as seen from the land side. Fig. 1 shows the general design of the well with the equipment; but minor details have been omitted, and, to avoid confusion, some parts have been shown out of the true section.

Construction.—After leveling off the site, the steel-plate, cutting shoe was set up, and the forms were erected over it. The forms were of 2-in. sheathing nailed to waling pieces cut to radius. Those for the

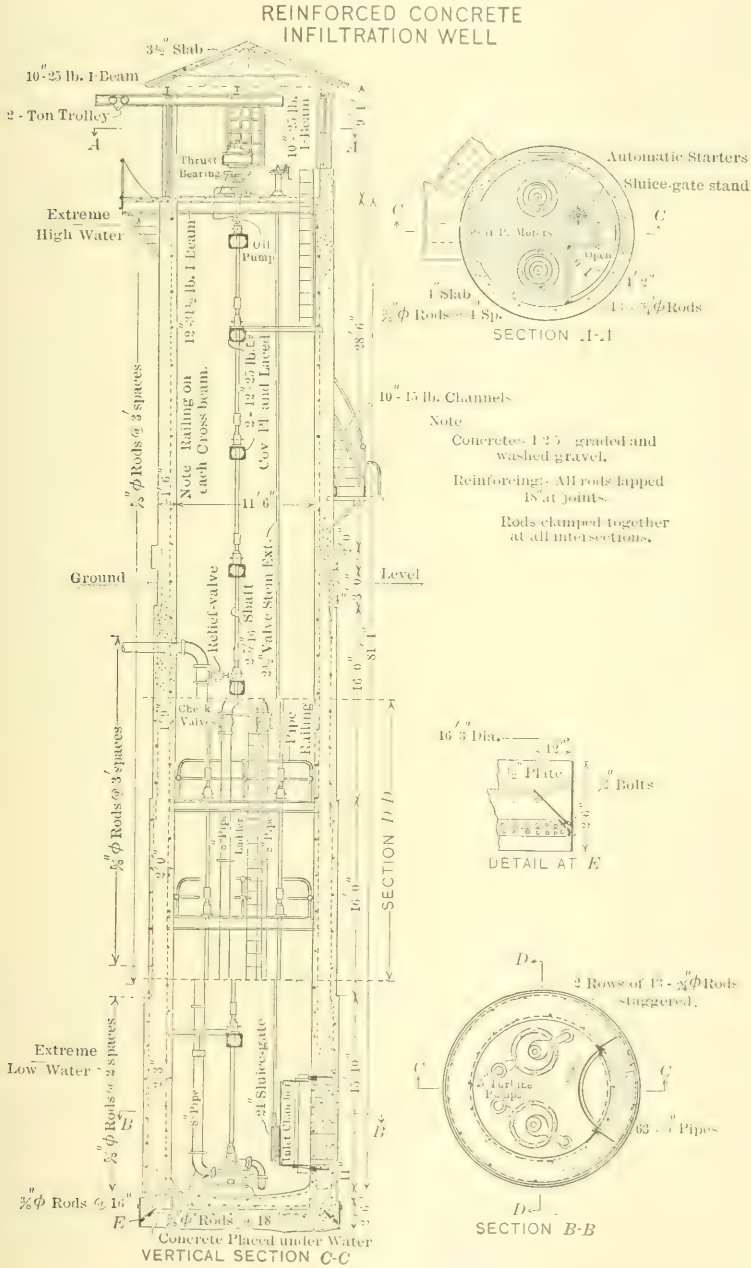

REINFORCED CONCRETE INFILTRATION WELL
3½" Slab
10"-25 lb. I-Beam
2 - Ton Trolley
Thrust Bearing
10"-25 lb. I-Beam
Extreme High Water
Oil Pump
Note Railing on each Cross beam.
⅜" ϕ Rods @ 3' spaces
Ground
Level
Relief-valve
Check Valves
Pipe Railing
SECTION D-D
⅝" ϕ Rods @ 3' spaces
Extreme Low Water
8" Pipe
Sluice-gate
⅝" ϕ Rods @ 16"
Concrete Placed under Water
VERTICAL SECTION C-C
Automatic Starters
Sluice-gate stand
SECTION A-A
10"-15 lb. Channels
Note
Concrete:- 1:2:5 graded and washed gravel.
Reinforcing:- All rods lapped 18" at joints.
Rods clamped together at all intersections.
DETAIL AT E
2 Rows of 13 - ⅝" ϕ Rods staggered.
SECTION B-B

Fig. 1.

outside of the wall were supported by the posts of the working platform, and were held together, in sections, by steel bands arranged so that they could be loosened to allow the wall to slip through them. The inside forms were hung from cantilever brackets on the working platform, and were held in position by removable cross-braces, a construction which permitted the free use of the entire interior during the periods when excavating was being done.

The reinforcing rods were put in position, and a section of concrete about 5 ft. high was carefully placed and allowed to set. The forms were then loosened, and the material was excavated from the inside by a $\frac{3}{4}$-yd. orange-peel bucket handled by a derrick. As the excavation progressed the wall gradually sank. The operations of placing concrete and excavating were carried on alternately until the foot of the shaft reached its final position. The shell sank very freely through the earth, and it became necessary to provide some means of checking its descent at the proper place. This was accomplished by forming a concrete collar, integral with the wall, just above the ground level, and then taking a part of the load off the cutting shoe by blocking between this collar and the ground surface. The collar was designed to carry a large part of the suspended weight of the well if necessary. By the use of the collar the sinking of the wall was stopped at the proper place, and there was no settlement while the sand was being removed from beneath the cutting shoe.

Before the shaft reached the water level, the intake chamber was bolted in position and the sluice-gate was attached to it. When the excavation reached the water level, a large pulsometer pump was used to remove part of the water and fine sand.

As the flow of water through the open bottom of the shaft was too great to be handled by pumps, a diver was sent down to level off the bottom of the excavation and place the reinforcement for the rough bottom of the well; he also distributed the concrete for this bottom. After allowing the concrete to harden, the well was pumped dry and the finished bottom was put in.

The upper part of the shaft was constructed by raising the forms by stages as the wall was completed, and no conditions unusual to the construction of similar structures were encountered.

After the shaft was completed, the steel, guide-bearing supports were placed, leveled up, and grouted in place. Great care was required

in getting the supports and bearings perfectly level and plumb, so that the vertical shafts would run smoothly.

This pumping plant has been in operation for some time, and it has been found, as anticipated, that the water reaching the interior of the well is free from suspended earthy matter, although at times the river has been quite turbid. At no time has there been a shortage of water in the well, even when the pump was running at its rated capacity and the river stage was very low.

The construction of that part of the well below the ground level was accomplished in 18 working days, and the entire part above ground in 6 working days.

As the construction of the well was only a small part of the work done at Silver Grove, and as the entire job has not been closed up, only approximate costs can be given. The figures show the actual costs of construction, and do not include engineering, drafting, and other overhead charges.

Grading and excavation................	370 cu. yd. at $1.65
All concrete, including reinforcement, material	280 " " " 3.15
All concrete, including reinforcement, labor	280 " " " 3.85
All forms, material, and labor..........	at $2.85 per cu. yd.
All steelwork, fabricated and otherwise, material	28 000 lb. at $0.052
All steelwork, fabricated and otherwise, labor	28 000 " " 0.022
(Costs of steel include painting.)	
All equipment, piping, wiring, etc., in place..........	$6 200

This pumping station was designed, constructed, and equipped by Westinghouse, Church, Kerr and Company, of New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

AIR RESISTANCES TO TRAINS IN TUBE TUNNELS.

By J. V. Davies, M. Am. Soc. C. E.

To be Presented May 15th, 1912.

Introduction.

The development in recent years of tube tunnels and subways with close clearances, as integral parts in the construction of high-speed, electrically-operated railways for passenger transportation, has opened questions of somewhat serious moment in the operation of such lines, which had not previously been considered, although under these new conditions they have a material bearing on the operation, and should have some consideration in the design under which such tunnels are constructed.

An interesting question of this character, regarding which, as far as the writer can find, little information has been published or is available, is that of the resistance of air and the movement of columns of air in the operation of trains in tube tunnels. There has been available a considerable mass of information as to the resistance of air and pressures on trains operating in the open, but it will be obvious that such information has comparatively little, if any, bearing on this question when trains are operated in a confined aperture such as a tube tunnel, where the relation of the cross-section of the aperture to the cross-section of the moving train introduces features which in no

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and when finally closed, the papers, with discussion in full, will be published in *Transactions*.

possible way relate to the same pressures and the same conditions as when the train is operated in the open.

In the development of the Hudson and Manhattan Railroad the line has recently been extended in Jersey City to a connection on the surface of the ground with the tracks of the Pennsylvania Railroad near Prior Street, and a through service between New York City and Newark has been put in operation by electrically-operated trains of the tunnel type, running at high speeds. Consequently, there is introduced the operation of these same trains at varying speeds over the tracks of the Pennsylvania Railroad, across Newark Meadows, and through the tube tunnels of the Hudson and Manhattan system to Church Street in the Borough of Manhattan. The question, therefore, of the power necessary to overcome these air resistances, is an important one.

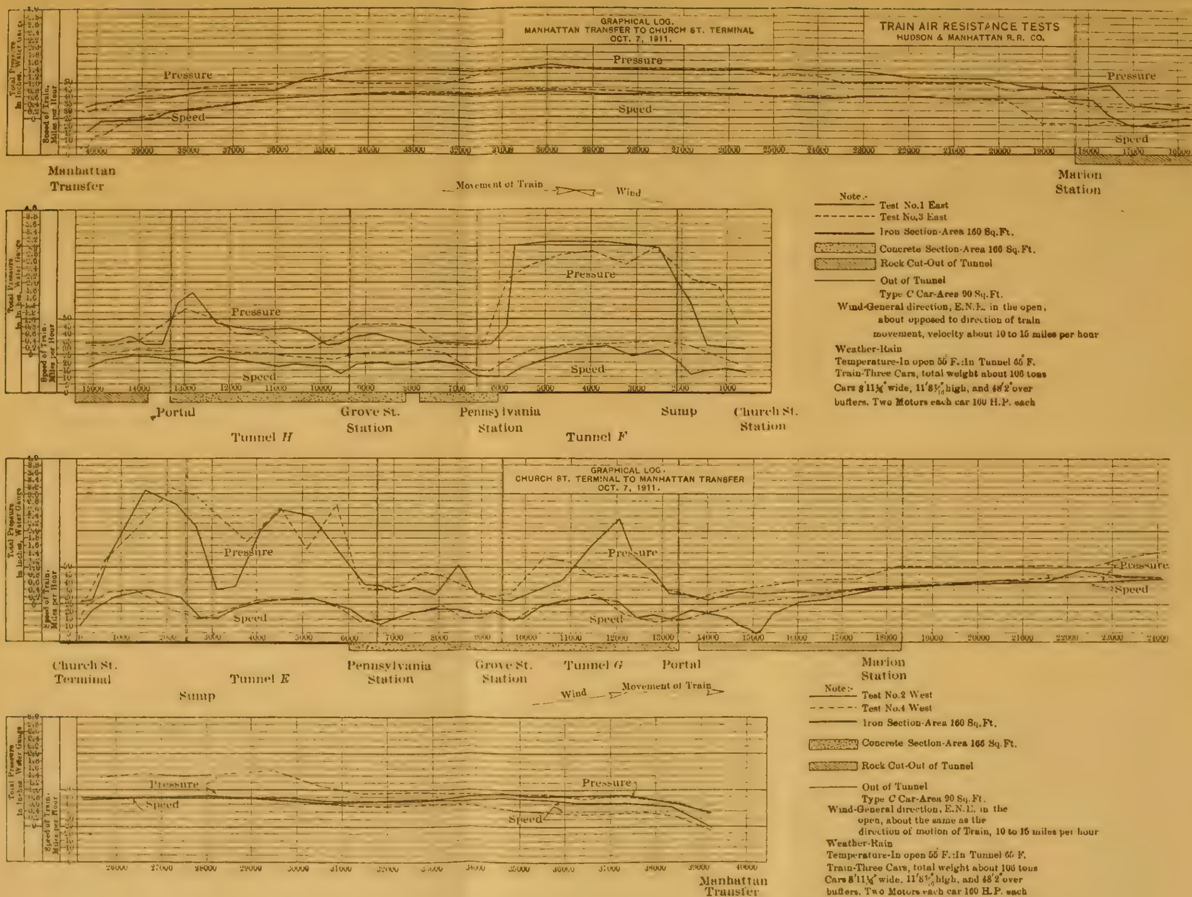
In discussing the paper by George Gibbs, M. Am. Soc. C. E., on the New York tunnels of the Pennsylvania Railroad, the writer stated* that he had made some interesting experiments in relation to air resistances in tube tunnels, which at that time were not completed. Since then the substance of these experiments has been completed and is presented herewith. The results of the experimental tests of the conditions arising from the joint train operation, above mentioned, the writer presents, principally as a series of facts, with certain deductions drawn therefrom.

The formulas, given later, have either been deduced from the plotting of the actual results obtained in the experiments, or have been based on formulas elsewhere published for air resistances in the open air, introducing coefficients which have been obtained from the results of these experiments.

The subject matter of this paper is presented in the hope of starting discussion or drawing out information as to similar tests under corresponding conditions, which may be of assistance in the general proposition of ventilation and power consumption necessary in the operation of trains in tunnels constructed for transportation purposes, or from which may be obtained more definite information than is at present available, which may be of service to the Engineering Profession in the development of similar problems in the future.

---

* *Transactions*, Am. Soc. C. E., Vol. LXIX, p. 414.


TRAIN AIR RESISTANCE TESTS
HUDSON & MANHATTAN R.R. CO.
GRAPHICAL LOG.
MANHATTAN TRANSFER TO CHURCH ST. TERMINAL
OCT. 7, 1911.
Total Pressure in Inches, Water Gauge
Speed of Train, Miles per Hour
Pressure
Speed
Manhattan Transfer
Marion Station
Movement of Train
Wind
Portal
Grove St. Station
Pennsylvania Station
Sump
Church St. Station
Tunnel H
Tunnel F
Note:-
Test No.1 East
Test No.3 East
Iron Section-Area 160 Sq.Ft.
Concrete Section-Area 166 Sq.Ft.
Rock Cut-Out of Tunnel
Out of Tunnel
Type C Car-Area 90 Sq.Ft.
Wind-General direction, E.N.E. in the open, about opposed to direction of train movement, velocity about 10 to 15 miles per hour
Weather-Rain
Temperature-In open 50° F.: In Tunnel 65° F.
Train-Three Cars, total weight about 106 tons
Cars 8'11¾" wide, 11'8 1/16" high, and 48'2" over buffers. Two Motors each car 160 H.P. each
GRAPHICAL LOG.
CHURCH ST. TERMINAL TO MANHATTAN TRANSFER
OCT. 7, 1911.
Church St. Terminal
Sump
Tunnel E
Pennsylvania Station
Grove St. Station
Tunnel G
Portal
Marion Station
Manhattan Transfer
Note:-
Test No.2 West
Test No.4 West
Iron Section-Area 160 Sq.Ft.
Concrete Section-Area 166 Sq.Ft.
Rock Cut-Out of Tunnel
Out of Tunnel
Type C Car-Area 90 Sq.Ft.
Wind-General direction, E.N.E. in the open, about the same as the direction of motion of Train, 10 to 15 miles per hour
Weather-Rain
Temperature-In open 55° F.: In Tunnel 65° F.
Train-Three Cars, total weight about 106 tons
Cars 8'11¾" wide, 11'8 1/16" high, and 48'2" over buffers. Two Motors each car 160 H.P. each

Test Runs.

On the morning of October 7th, 1911, tests were made to determine train resistances, with special reference to the resistance offered to train movement by the air, both in and out of the tunnels of the Hudson and Manhattan Railroad and on the surface tracks of the Pennsylvania Railroad between Jersey City and Manhattan Transfer. These tests were made in the early morning (from 1.20 A. M. to 5.00 A. M.) when there was practically no other traffic in the tubes. The test runs and their numbers are listed in Table 1; the graphical log for the first four is shown on Plate XXX.

TABLE 1.—Test Runs.

Run No.	From:	To:	Object of test.
1-*E*	Manhattan Trans.	Church Street	Resistance.
2-*W*	Church Street	Manhattan Trans	"
3-*E*	Manhattan Trans.	Church Street	"
4-*W*	Church Street	Manhattan Trans.	"
V-5-*E*	Manhattan Trans.	Church Street	Velocity.
V-6-*W*	Church Street	Manhattan Trans.	"

Tests Nos. 1 to 4, called Resistance Tests, were made for resistance determination only; no air velocity readings were taken.

Tests Nos. 5 and 6, called Velocity Tests, were made for air velocities; that is, to determine the "slip" in the tunnels. By "slip" is meant that portion of the air which is not dispelled or given the same motion as the train, but either remains at rest or is deflected by the front of the train and passed back to the rear end.

Line.—The distance from Manhattan Transfer to Church Street Terminal is 40 454 ft., or 7.66 miles. Of this distance, 13 400 ft. is over the tracks of the Hudson and Manhattan Railroad, and is in tunnels (partly iron tubular and partly concrete lined); the remainder is over the tracks of the Pennsylvania Railroad, and is in the open.

On leaving Manhattan Transfer, the track passes over the Hackensack Meadows to Marion Station, a distance of about 4¼ miles. Throughout this distance the right of way is unprotected by cuts or buildings, and is practically on level grade, and with very slight curvature. From Marion Station to the Portal, 4 600 ft., the track passes through a rock cut, from 20 to 30 ft. deep, and wide enough for four

tracks in some parts and for six or more in others. On entering the Portal the line passes through a single-track concrete tunnel (H. & M. standard, 14-ft. section, as shown by Fig. 1 and Plate XXXI) to the Pennsylvania Station (Jersey City).

There is no exit for the air, from the Portal to a point just west of Grove Street Station (4 000 ft.), but at that point, through an enlargement, the air can escape from one tube to another, or to the surface by way of the station passages. Between Grove Street and the Pennsylvania Station there are two enlargements, and the total distance is 2 800 ft.

Leaving the Pennsylvania Station, the tunnel is of standard iron construction (15 ft. 3 in. diameter inside of lining plate flanges, as shown by Fig. 1 and Plate XXXI), and this extends to Church Street (6 600 ft.) with no outlet for the air except at the Church Street end. The maximum rate of grade of the tunnel from the center of the river to Church Street is 4.63 per cent.

Area of Tunnels.—The net internal area of the concrete section of the tunnels is 166 sq. ft.; that of the iron section is 160 sq. ft.

Weather.—Rain was falling throughout the tests. Run No. 1-*E* was made in a very heavy rain; the others, with the exception of the last part of No. 4-*W*, were made in a more moderate rain.

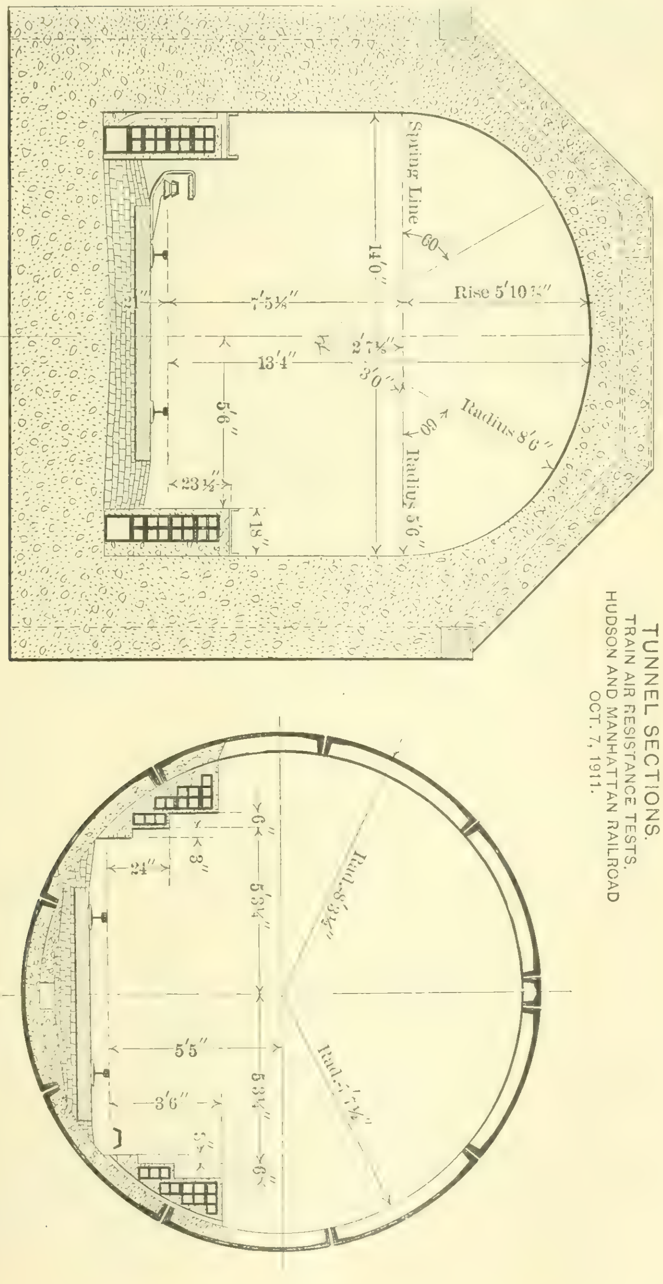
Temperature.—The temperature in the tunnel was approximately 65° Fahr.; that in the open was approximately 55° Fahr.

Wind.—The wind was east-northeast, and was blowing at about 15 miles per hour. The direction of the wind was such that in the east-bound runs the train was running almost against the wind, while in the others it was running nearly before it.

Make-Up of Test Train.—The test train consisted of three Hudson and Manhattan Railroad Company's Type "C," steel, motor cars. On account of the arrangement of the apparatus, the pressure runs had to be made with the train heading in the same direction. The total weight of cars and crew was about 106 tons.

The following are the principal dimensions of the cars:

Length over all..........................	48 ft. 5 in.
Width over all..........................	8 ft. 11¼ in.
Height above top of rail..................	11 ft. $8\frac{7}{16}$ in.
Center to center of trucks................	33 ft. 0 in.



Concrete Tunnel.
Area 163 sq.ft.

Iron Tunnel.
Area 160 sq.ft.

Fig. 1.

Wheel base.	Motor truck	6 ft. 6 in.
	Trailer truck	5 ft. 6 in.
Diameter of wheels.	Motor truck	34¼ in.
	Trailer truck	30 in.
No. of passengers.	Seated	44
	Total	150
Weight, in pounds.	On motor truck	41 730
	On trailer truck	27 890
	Total	69 620
Motors for each car.	Number	2
	Rating, each	160 h.p.
Cross-sectional area		90 sq. ft.

Arrangement of Apparatus.—The arrangement of the apparatus for both resistance and velocity tests is shown by Fig. 2.

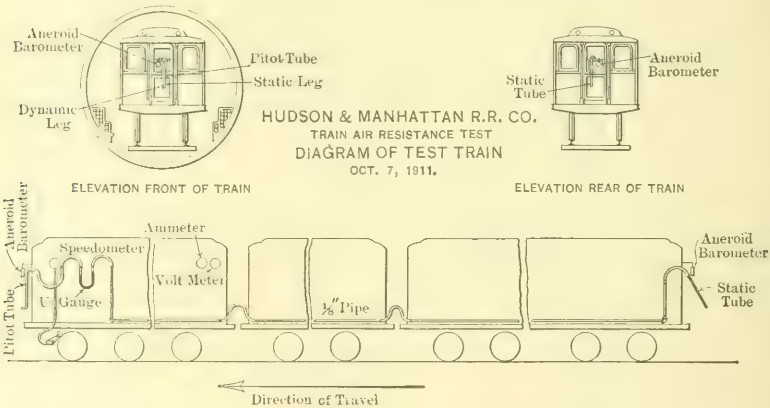


Fig. 2.

Resistance Tests.

Speed. A Warner autometer, with railroad attachment, was used for the speed determination. The driving wheel of the mechanism was attached to the forward truck frame and was driven off the tread of the truck wheel. The flexible shaft from this wheel passed up through the floor of the car to the dial in the front vestibule.

Pressure.—A Pitot tube was held outside the window in the front door of the train, with the dynamic leg connected to one leg of a

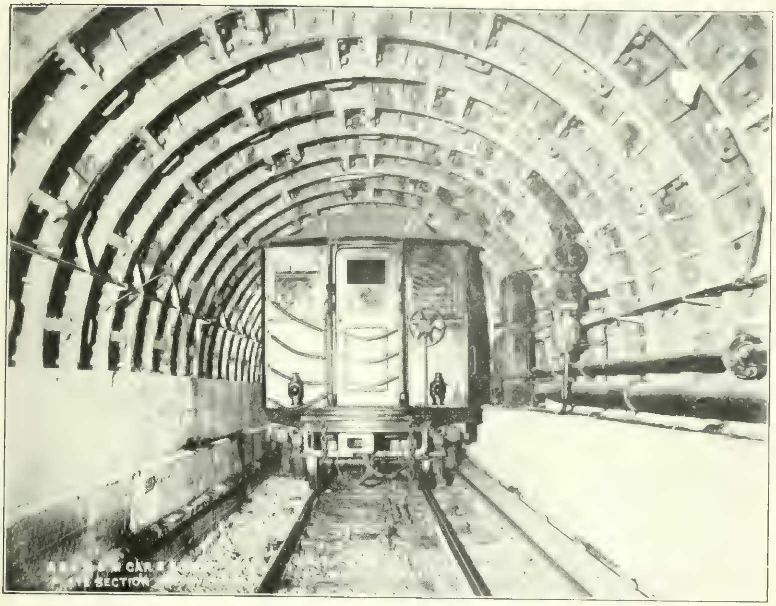


FIG. 1.—CAR IN IRON-LINED TUNNEL.

FIG. 2.—CAR IN CONCRETE-LINED TUNNEL.

U-tube, the opening in the dynamic leg looking in the direction of train movement. The other leg of the U-gauge was connected by a rubber hose to a $\frac{1}{8}$-in. pipe which extended the length of the train, the connections between the cars being made with rubber hose.

Outside the window in the rear door of the train a static tube was held, with its opening at right angles to the direction of motion of the train. This tube was of brass, having an inside diameter of $\frac{5}{32}$ in. with the end blanked. A very small hole (about $\frac{1}{128}$ in. in diameter) was drilled in the side of the tube. This static tube was connected to the $\frac{1}{8}$-in. pipe line, and the resultant reading of the U-gauge gave the total pressure, in inches, water gauge, the plus pressure in the front automatically adding itself to the minus pressure at the rear.

Outside the front and rear windows were also hung aneroid barometers, and the increase in pressure at the front was added to the decrease in pressure at the rear; the results, when the proper correction was made for elevation, gave the total pressure. Of course, the aneroid pressure should check with that found by the Pitot tube, and it was found that it did so, excepting that when the total pressure reached $1\frac{1}{2}$ in., water gauge, or greater, either the hose connections of the tubes, the pipe line itself, or the line connections between the cars, leaked, thus destroying the vacuum at the rear end. At all lower pressures the tube and aneroid readings checked very closely; in fact, in many instances, the readings were identical.

Horse-Power.—An ammeter and volt meter were set in the front car in order to measure the power input to the motors. This method gave the power consumption of the train, but, in calculating the results, it was very difficult to find just what part of this power was expended to overcome speed resistance and what part to overcome other resistances, such as those due to acceleration, grade, etc. The change in speed—acceleration or retardation—proved especially bothersome, as the train was found to change almost continuously.

Velocity Tests.

Each leg of the Pitot tube was connected to a leg of the U-gauge. The tube was held between the first and second cars of the train, with the opening of the dynamic leg looking in the direction of train motion, the end projecting beyond the car body.

Method of Tests.

Resistance Tests.—Two men were stationed at the rear of the train—one to read the rear aneroid and the other to record the results. Readings were commenced when the train left the starting point and were kept up continuously until the other terminal was reached. These readings were recorded for each interval of 15 sec., the number of readings per interval varying from 3 or 4 to 6 or 8.

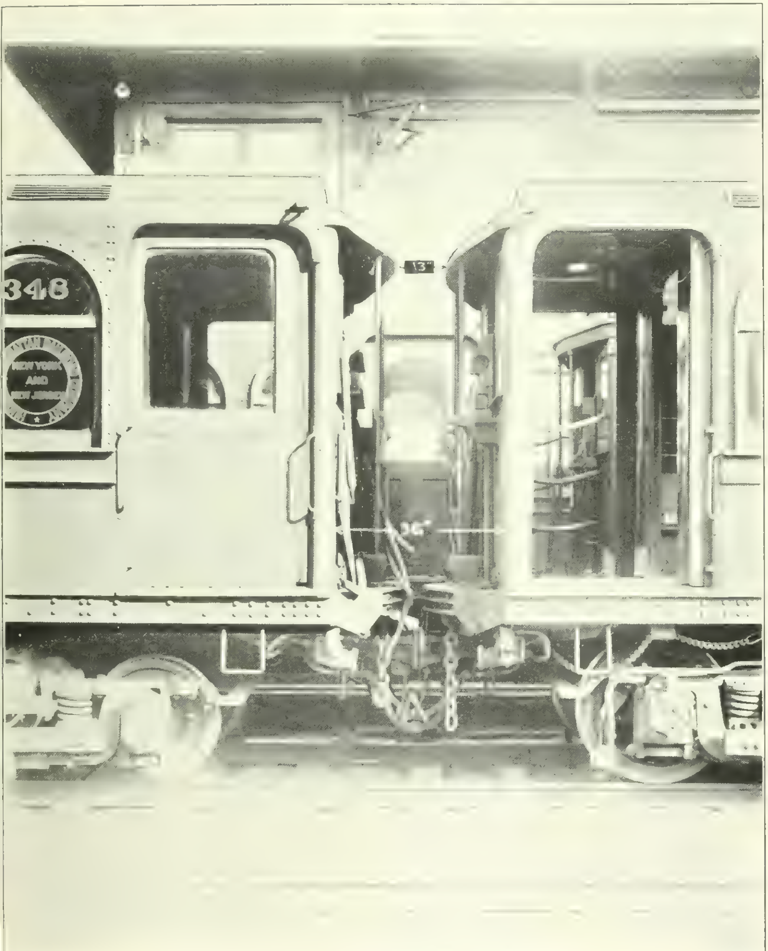
One observer read the ammeter and volt meter and another recorded the readings, dividing them into intervals of 15 sec. The voltage was found to be quite constant for the different sections, depending on the distance between feeders and the pressures carried at the several sub-stations. The current consumption varied considerably, depending on the speed, grade, etc.

At the front end one observer read the speedometer, another the U-gauge, and a third the front aneroid. A fourth man kept the time divided into 15-sec. intervals, the same as in the other readings, and also gave the time of passing stations, entering tunnels, or other special points, so that the relation between the readings and the location of the train could be determined. Two men recorded these readings.

Velocity Tests.—In the velocity tests no readings were made of the resistance or power consumption. As mentioned before, the tube was held out of the opening between the cars, the position being changed from the right side, to the the top, and to the left side.

As each leg of the Pitot tube was connected to the U-gauge, the resultant reading was the pressure due to the velocity only. The velocity corresponding to this pressure gave the gross air velocity, and from this should be deducted the speed that the tube itself was moving, the train speed, and this difference, or net velocity, was the velocity of the air passing back at the side of the train. The speed of this air, when multiplied by the area, gave the quantity passing back, or the "slip." Care was taken to have the tube project as far from the car as possible, for it was found that a body of air surrounding the car moved with it, that is, the effective area of the car was more than that of the actual section.

No attempt was made to find the resistance due to impact of other than the front car. This impact amounted to a little, but as the



SPACE BETWEEN CARS.

openings between the cars were small, as shown on Plate XXXII, it has been neglected on account of the difficulty attached to the measurement.

Graphical Logs.

Two graphical logs, Plate XXX,* have been plotted, one for the east-bound and one for the west-bound resistance runs. The second and fourth runs are shown by dotted and the first and third by solid lines. The location, or distance, on the charts, was laid off horizontally on a scale of $\frac{1}{8}$ in. to 100 ft., and the light vertical lines give the 1 000-ft. marks. The numbers on these lines give the distances from the Church Street Terminal. The double vertical lines give the position of such locating points in the run as stations, entrances to tunnels, etc.

The lower lines are the speed curves, and give the speed of the train, in miles per hour, plotted as the average speed for the 15-sec. intervals, at the middle point of the distance covered in the 15 sec. These points are joined, and the resulting line represents the speed.

The next group gives the average net pressure, in inches, water gauge. The points are plotted directly above those for the speed, and the line joining these points gives the pressure curve. The magnitude of this pressure, when below $1\frac{1}{2}$ in., water gauge, is the average of the U-tube and corrected aneroid readings; when above $1\frac{1}{2}$ in., water gauge, it is the aneroid only. All the U-gauge and aneroid readings for the interval are averaged before the final average is taken.

The two upper curves are calculated from the pressure curves, and show the total air resistance that the train had to overcome. The points on these curves are calculated by multiplying the area of the car by the unit pressure, the result being total pounds.

East-bound Runs.—In the east-bound runs, as stated previously, the general direction of the train movement in the open was almost against the direction of the wind, and the air resistance, therefore, was increased over the west-bound runs, where the train was running with the wind. This resistance is shown very clearly on the air resistance curve in the open, Fig. 3, which will be described later.

It will be noticed that in the open the pressure curve, and conse-

* This plate is reproduced from Plate CXVII, in *Transactions*, Am. Soc. C. E., Vol. LXIX, p. 417, and does not indicate resistance curves.

quently the resistance, follows, with a few exceptions, the speed curve. The deviations in the pressure curve are probably due to errors in readings. On entering the rock cut, the speed had to be reduced on account of switches, and, therefore, no conclusion may be drawn as to the effect of entering the cut.

The two most salient features that are noticeable on the east-bound runs (Plate XXX) are the enormous jumps in pressure as the train enters the tunnels at the Portal and at the Pennsylvania Station for the trip under the river. When the large volume of air that has to be set in motion is considered, these pressures appear to be almost too low. The column of air in front of a train leaving the Pennsylvania Station for Church Street is about 6 000 ft. long, and if a section is taken the same as the car, 90 sq. ft., it would contain 540 000 cu. ft., and, at 62° Fahr., would weigh about 41 000 lb. This whole volume, if given an acceleration of 15 ft. per sec. (10 miles per hour per sec.), would require a total pressure of 19 200 lb. Of course, this is assuming that the air is solid and does not compress, and that it acts as a fluid. On account of the characteristics of air, it is impossible to calculate what this inertia pressure would be.

During the day, when traffic is heavy, this impact pressure will not be as high as that found in these trials. This is due to the fact that the train is not required to start this large volume of air from rest. From previous anemometer tests it has been found that during the day, when the trains are on 3 min. headway, the air in the river tunnels is rarely stationary, the velocity depending on the position of the train in the tube.

When a train enters the tube, an observer at the other end will notice an increase in the velocity of the air, which will increase as the train approaches, and reach its maximum as the train reaches his position. After the train passes, there is a very great rush of air (the filling of the vacuum caused by the train) for a short period, and this dies down as the train recedes; but, even after the train leaves the tunnel, some flow is noticeable, due to the momentum of the body of air, the effect of a train approaching in the same tunnel, but on the other side of an enlargement, and to the exhaust of trains in another tube which short-circuits at the station, in the case of an island platform, and enters the other tunnel.

Observations taken during the night, when the trains are running

infrequently, such as every half-hour or less, show that the air will come to rest, and in some tunnels where the air passages at enlargements or stations permit it, will reverse, due to the movement of trains in the other tunnels. Therefore, the force necessary to overcome the air inertia will depend on the density of traffic.

At the time these tests were made, the traffic was very light, and it is fairly safe to assume that in the major part of the runs the air was at rest when the train entered the tunnel. Comparisons made with the entry pressures found in these runs and those for previous tests made in the day, show that the entering resistance when trains are frequent is about 85% of that found at night.

As the train enters the tunnel it is resisted by two air forces: one the impact and the other the static resistance due to moving the column of air. The first is independent of the length of tunnel or air columns in front of the train, while the latter varies directly with the length of the column. It is seen, therefore, that in long tunnels the total resistance does not depend on the speed alone, and, therefore, to some extent, the pressure line does not follow the speed line. This subject will be treated more fully later.

West-bound Runs.—On leaving Church Street Terminal (Plate XXX) and entering the tunnel, the same characteristic jump in pressure is encountered. Near the center of the tunnel a maintenance gang was at work, and the speed had to be reduced materially. This caused the drop in pressure shown for both runs. After passing this point the pressure increased with the speed, until the Pennsylvania Station was reached. Another gang was at work in Tunnel *G*, midway between Grove Street Station and the Portal. This caused another slow-down and a drop in pressure. The large increase in pressure just east of the portal in test No. 2-*W* is due, to some extent, to the speed, but appears to be somewhat high.

In the open, the runs in this direction were almost before the wind, and this was very noticeable in Test No. 2-*W*, where at times, in place of a minus pressure at the rear, a zero pressure, and, in some instances, a plus pressure, was found.

Air Resistance in the Open.—On Fig. 3 has been plotted the air resistance encountered in the open at different speeds, in pounds. The lower curve (dotted) is the resistance when running with the wind, and the upper curve (light) is the resistance when running

against the wind. The center curve has been drawn midway between these two, and gives the resistance with no wind. The curve on the upper part of the sheet is the corresponding horse-power, calculated from the center curve, or the resistance with no wind.

As mentioned before, the number of cars in the train would have some effect on the resistance due to impact on each coach end, but no account has been taken of this, except that any extra resistance due to this action would be included in the miscellaneous resistance. It is fairly safe to say that for cars of this cross-section, independent of the weight of the train and the number of cars, the resistance offered to the movement of the train by the air, would be as shown.

The curve is fairly flat until a speed of 30 miles per hour is reached, when the upward tendency is more marked. After 40 miles per hour the curve goes up nearly straight. This feature is borne out by other experiments and by the consideration that the impact, or speed air resistance, varies with some function of the square of the velocity.

Formulas.—The air resistance in the open must be wholly due to impact. Now, if it is assumed that the air which is acted on is given a velocity equal to that of the car, the results will be the same as if the car remained at rest and the air was blowing by the car at the train velocity. Then the magnitude of the pressure (*i. e.*, due to jet) bears to the weight of air flowing in a second the same ratio which the velocity per second of change in motion of the stream of air bears to the velocity generated by gravity in a second.

Working from this assumption, a formula has been worked out, the derivation being given in the Appendix.

The total resistance, in pounds, is as follows:

For speeds up to 32 miles per hour:

$$P = 0.0672\ D\ A\ V^2\ (1.772 - 0.0382\ V) \qquad (7)$$

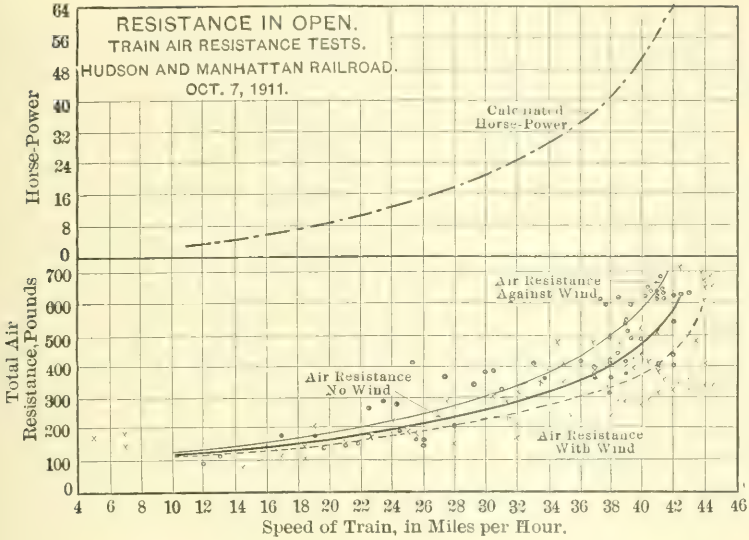
For speeds greater than 32 miles per hour:

$$P = 0.0672\ D\ A\ V^2\ (0.0182\ V - 0.03) \qquad (8)$$

For cars of 90 sq. ft. sectional area, and for an air temperature of 52° Fahr., these formulas become:

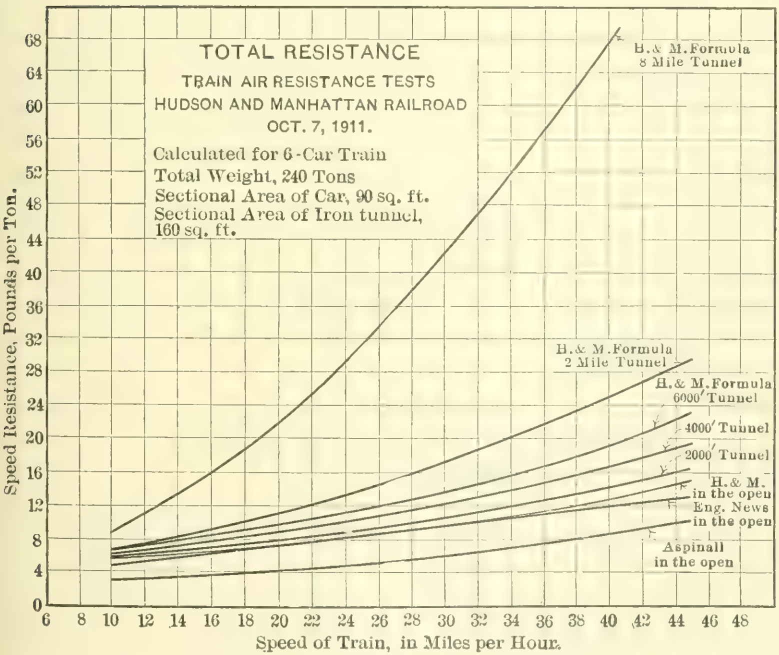
For speeds up to 32 miles per hour:

$$P = 0.468\ V^2\ (1.772 - 0.0382\ V) \qquad (9)$$



RESISTANCE IN OPEN.
TRAIN AIR RESISTANCE TESTS.
HUDSON AND MANHATTAN RAILROAD.
OCT. 7, 1911.
Horse-Power
Calculated Horse-Power
Total Air Resistance, Pounds
Air Resistance Against Wind
Air Resistance No Wind
Air Resistance With Wind
Speed of Train, in Miles per Hour.

FIG. 3.



TOTAL RESISTANCE
TRAIN AIR RESISTANCE TESTS
HUDSON AND MANHATTAN RAILROAD
OCT. 7, 1911.
Calculated for 6-Car Train
Total Weight, 240 Tons
Sectional Area of Car, 90 sq. ft.
Sectional Area of Iron tunnel, 160 sq. ft.
B. & M. Formula 8 Mile Tunnel
B. & M. Formula 2 Mile Tunnel
H. & M. Formula 6000′ Tunnel
4000′ Tunnel
2000′ Tunnel
H. & M. in the open
Eng. News in the open
Aspinall in the open
Speed Resistance, Pounds per Ton.
Speed of Train, in Miles per Hour.

FIG. 4.

For speeds greater than 32 miles per hour:

$$P = 0.468\ V^2\ (0.0182\ V - 0.03) \quad \text{.....................(10)}$$

in which P = Total air resistance, in pounds;

V = Train speed, in miles per hour;

D = Weight of the air, in pounds per cubic foot;

and A = Cross-sectional area of the car, in square feet.

Miscellaneous Resistances.—By miscellaneous resistances is meant the resistances other than air that appear when the train is running at constant speed on a level tangent. These are the resistances caused by journal friction, center-bearing friction, flange friction, etc., and depend to a great extent on weather conditions and temperature. As previously stated, any impact resistance due to gaps between cars in a train is included in this item.

On Fig. 4 a curve is shown marked "H. & M. in the open." This curve is the total resistance, in pounds per ton, to motion of the train when running at uniform speeds on a level tangent.

As mentioned before, it was very difficult to use the horse-power readings, because the train was seldom at constant speed, and, in the tunnels, so many other resistance-producing factors entered, such as grade, curve, etc., that a speed-resistance calculation was almost impossible; however, enough readings, at constant speed in the open, were available to plot, as shown on Fig. 4, the horse-power being reduced to its corresponding resistance in pounds per ton, and an allowance of 25% being made for motor and gear losses.

The air resistance in the open was then reduced to pounds per ton for the different speeds and taken from the total resistance; these values, therefore, are the miscellaneous resistance. This miscellaneous resistance, when plotted against the speed, is a straight line, the equation of which is:

$$P = 4 + 0.1\ V \quad \text{.....................(11)}$$

in which P = Miscellaneous resistance, in pounds per ton;

and V = Train speed, in miles per hour.

Total Resistance in the Open.—The total resistance to motion of trains in the open, at constant speed, is then the sum of the miscellaneous and air resistances.

The formulas, expressed in general terms, are:

For speeds up to 32 miles per hour:

$$R = 4 + 0.1\ V + \frac{0.0672\ D\ A\ V^2\ (1.772 - 0.0382\ V)}{W\ N} \ldots\ldots (12)$$

For speeds greater than 32 miles per hour:

$$R = 4 + 0.1\ V + \frac{0.0672\ D\ A\ V^2\ (0.0182\ V - 0.03)}{W\ N} \ldots\ldots (13)$$

For air temperatures of 52° Fahr., and for cars of 90 sq. ft. section, the formulas become:

For speeds up to 32 miles per hour:

$$R = 4 + 0.1\ V + \frac{0.468\ V^2\ (1.772 - 0.0382\ V)}{W\ N} \ldots\ldots (14)$$

For speeds greater than 32 miles per hour:

$$R = 4 + 0.1\ V + \frac{0.468\ V^2\ (0.0182\ V - 0.03)}{W\ N} \ldots\ldots (15)$$

in which R = Total resistance, in pounds per ton;
V = Train speed, in miles per hour;
D = Density of air, in pounds;
A = Cross-sectional area of car, in square feet;
W = Weight of car, in tons;
and N = Number of cars in the train.

Velocity Tests.—The velocity tests were made in order to determine the slip, or the volume of air which is not dispelled by the piston action of the train. The results obtained in the iron tunnels are reasonable and have been used, but those found in the tunnels of concrete section have not been used, as the Pitot tube did not extend far enough from the coach body, or did not reach beyond the zone of influence of the car. It has been found that, on all sides of the car, there is a certain depth of air which moves along with the train. If the tube does not extend out past this air, the results are useless.

The slip, or volume of air which is not expelled by the train, is shown by the left-hand group on Fig. 5. It will be noticed that the volume increases very rapidly with the speed of the train.

In the right-hand group on Fig. 5 has been shown the volume of air which is pushed in front of the train. This quantity is ascertained by subtracting the total slip from the total volume which would be discharged if the train filled the tube completely. The volumetric efficiency has also been plotted. By the volumetric efficiency is meant

the ratio of the volume of air which is displaced to that which would be displaced if the train filled the tube completely.

It will be noticed that the volume of air displaced rises uniformly with the speed until near the end, when the curve shows a tendency to flatten. When one considers the great pressure difference between the front and rear of the train, this seems reasonable, for, as the speed increases, the plus at the front goes up and the minus at the rear goes down.

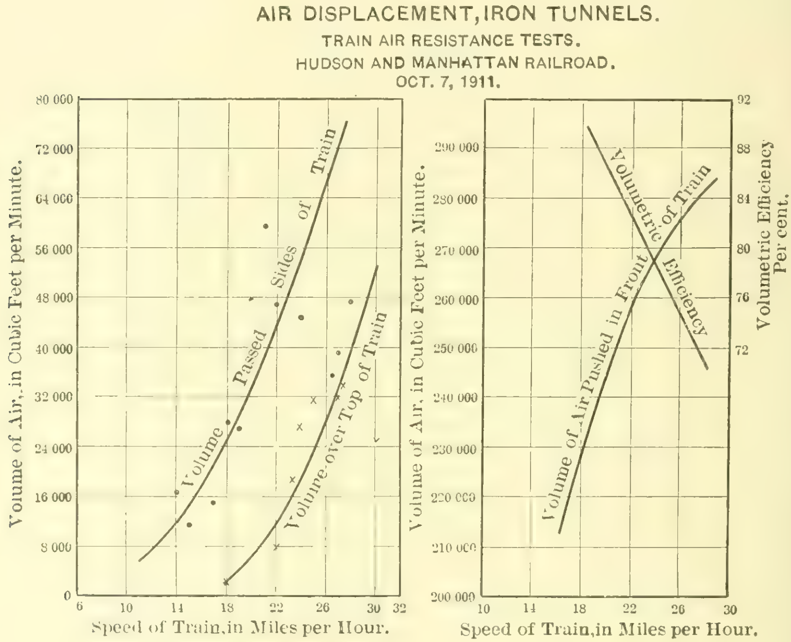


FIG. 5.

From the anemometer tests of 1909 and 1910 it was found that, for the average speed through the iron tunnels (3 min. for 6 500 ft., or 24 miles per hour), a steady flow of 190 000 cu. ft. per min. was developed. Now this 190 000 cu. ft. was the average taken for 2-min. readings, and of this 2 min., only 1½ min. were when a train was in the tunnel, the remainder being due to the flow induced by the passage of the train. Making this correction, it is found that, for a train moving at 24 miles per hour, the resultant velocity would be 1 590 ft. per min., and the corresponding volume would be 254 000 cu. ft. per min., which

checks fairly well with the volume given on the curve for 24 miles per hour (13 000 cu. ft. per min. less).

Air Resistance, Iron Tunnels.

The air resistance in tunnels is made up of two components: that due to impact (*i. e.*, the jet action of the train striking the air) and the static pressure, which is due to the resistance offered to the movement of the displaced air by the walls of the tunnel. There is also the skin friction of the train passing through the air. This would not amount to very much, and has been neglected.

The total pressure on the train would be a function of the sectional area of the car and tunnel, and would not depend on the longitudinal area of the train, for any pressures that existed on one side, tending to force the wheel flanges against the rail, would be counterbalanced by the same pressure on the other side of the train.

Impact.—The impact, as has been shown by the discussion of the resistances in the open, is independent of the length of the tunnel, and is governed by the speed and the quantity of air deflected by the car. The derivation of this formula is given in the Appendix.

The total pressure, in pounds, is

$$0.0761\ V^2\ (12.75 - 0.1809\ V) \qquad (18)$$

This formula has been calculated between the limits of 18 and 28 miles per hour, but, without doubt, is applicable to speeds somewhat below and above these figures, say, from 15 to 40 miles per hour. Outside of these speeds, the variations are so considerable that it would not appear wise to use the formula. The curve for impact is shown on Fig. 6.

Static Resistance.—As the static resistance is the pressure necessary to overcome the friction of the air passing through the tunnels, it will depend on the length of the tunnel, the smoothness of the surfaces, the speed, the radius of the bends, the size of the outlets, etc. Therefore, the formulas derived will be applicable, strictly speaking, only to the tunnels in which the tests were made, and should perhaps be modified for other tunnels.

The formula for this component of the air resistance has been worked out in the Appendix, and is:

Total pressure in pounds =

$$0.000205\ L\ V^2 \qquad (21)$$

in which L = Length of tunnel between train and air outlet, in feet;

and V = Train speed, in miles per hour.

The length of the iron tunnels where these tests were made is such that three curves may be plotted; one for 2 000, one for 4 000, and one for 6 000 ft., and the three curves thus marked on Fig. 6 give the total air resistance for tunnels having approximately these distances between air exits; these curves being the total air resistance, or impact plus the static resistance.

Total Air Resistance, Iron Tunnels.—The total air resistance will be the sum of the impact and static resistances, or the sum of Equations (18) and (21), or

$$P_a = 0.0761\ V^2\ (12.75 - 0.1809\ V) + 0.000205\ L\ V^2 \quad \text{..(22)}$$

Total Resistance, Iron Tunnels.—The total speed resistance for the iron tunnels, for a level tangent and a constant speed, will be the sum of Equations (11) and (22). The total resistance, in pounds per ton, will be:

$$P = 4 + 0.1\ V + \frac{0.0761\ V^2\ (12.75 - 0.1809\ V) + 0.000205\ L\ V^2}{W\ N} \quad \text{.(23)}$$

in which P = Total resistance, in pounds per ton;

L = Length between air exits, in feet;

W = Weight per car, in tons;

and N = Number of cars in the train.

AIR RESISTANCE, CONCRETE TUNNELS.

The total air resistance found in the concrete tunnels is plotted on Fig. 7, and also the calculated horse-power to overcome this resistance. These tunnels were shorter between air exits than the iron ones, the average distance being 3 000 ft.

Impact.—The formula for the impact resistance is derived in the Appendix, and is, in pounds:

$$P = 0.0745\ V^2\ (12.75 - 0.1809\ V) \quad \text{..................(24)}$$

This formula, when plotted for the different values of V, gives the curve shown on Fig. 7.

Static.—The vertical distance between the total air resistance curve as given and the impact curve, is the static pressure, and the formula, for the total resistance, in pounds, as worked out in the Appendix, is:

$$P = \frac{11.2\ V^2\ L}{700\ 000} \quad \text{.....................(26)}$$

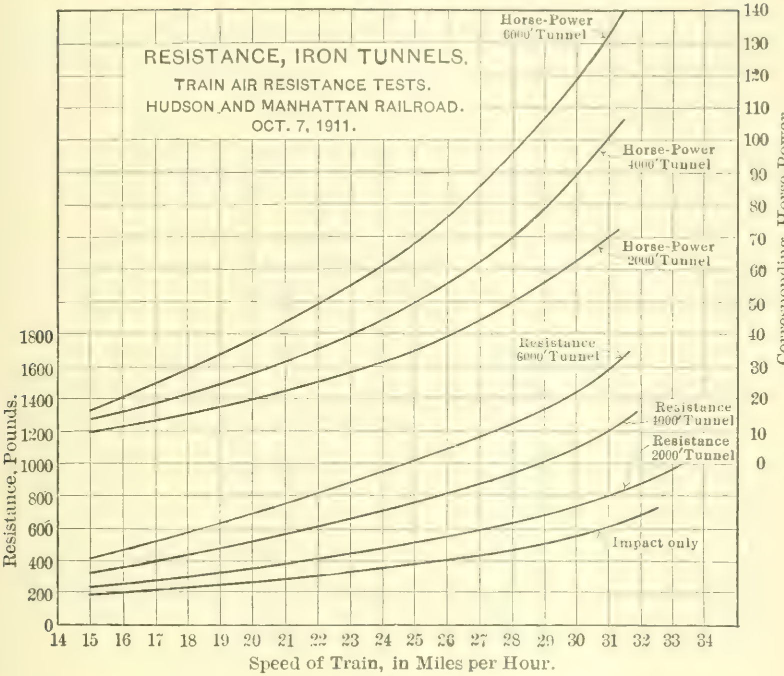

RESISTANCE, IRON TUNNELS.
TRAIN AIR RESISTANCE TESTS.
HUDSON AND MANHATTAN RAILROAD.
OCT. 7, 1911.
Horse-Power 6000' Tunnel
Horse-Power 4000' Tunnel
Horse-Power 2000' Tunnel
Resistance 6000' Tunnel
Resistance 4000' Tunnel
Resistance 2000' Tunnel
Impact only
Resistance, Pounds.
Corresponding, Horse-Power.
Speed of Train, in Miles per Hour.

FIG. 6.

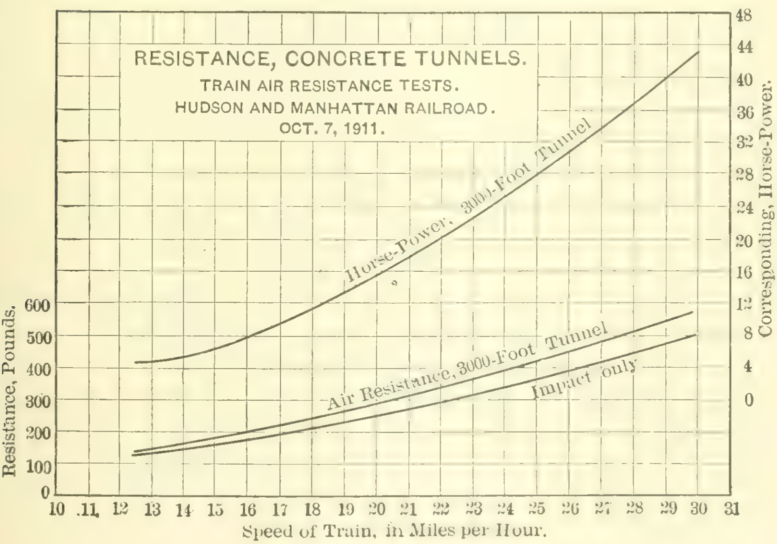

RESISTANCE, CONCRETE TUNNELS.
TRAIN AIR RESISTANCE TESTS.
HUDSON AND MANHATTAN RAILROAD.
OCT. 7, 1911.
Horse-Power, 3000-Foot Tunnel
Air Resistance, 3000-Foot Tunnel
Impact only
Resistance, Pounds.
Corresponding, Horse-Power.
Speed of Train, in Miles per Hour.

FIG. 7.

Total Air Resistance.—The total air resistance, in pounds, is the sum of the component resistances, or the sum of Equations (24) and (26), or

$$P = 0.0745\ V^2\ (12.75 - 0.1809\ V) + \frac{11.2\ V^2\ L}{700\ 000} \quad \ldots\ldots(27)$$

Total Speed Resistance.—The total speed resistance, in pounds per ton, will be the sum of Equations (11) and (27), or

$$P = 4 + 0.1\ V + \frac{0.0745\ V^2\ (12.75 - 0.1809\ V)}{W\ N} + \frac{11.2\ V^2\ L}{700\ 000\ W\ N} \quad ..(28)$$

Total Resistances.

On Fig. 4 the total resistances to train movement on a level tangent track, at constant speeds, have been plotted, assuming a 6-car train of 240 tons total weight. In all these curves the train speed has been plotted horizontally and the resistances, in pounds per ton of weight of train, vertically.

The lowest curve is plotted from the formula of Mr. J. A. F. Aspinall from his paper,* "Train Resistance," as follows:

$$P = 2.25 + \frac{V^{\frac{5}{3}}}{56 + 0.03\ l}$$

in which V = Train speed, in miles per hour;

P = Resistance, in pounds per ton;

and l = Length over coach bodies, in feet.

These tests were very carefully made in the open, but not with steel motor cars.

The next curve $\left(P = 2 + \frac{V}{4}\right)$ is one which was prepared by *Engineering News*.† This formula plots a straight line, and is found to coincide with the H. & M. curve from 18 to 33 miles per hour.

The third curve is the H. & M. in the open, and runs almost parallel with that of Aspinall, but is about 3 lb. above it. That may be due to the difference in the type of rolling stock.

The next three curves are plotted for H. & M. iron tunnels, 2 000, 4 000, and 6 000 ft. between openings.

* *Minutes of Proceedings*, Inst. C. E., Vol. CXLVII, p. 155, in which it is given as $P = 2.50 + \frac{V^{\frac{5}{3}}}{50.8 + 0.0278\ L}$ for tons of 2 240 lb., and constants are changed for tons of 2 000 lb.

† October 31st, 1901.

The next curve is plotted for an iron tunnel of 160 sq. ft. section and 2 miles between air exits. It will be noticed that, at 45 miles per hour, the total resistance is 30 lb. per ton. Assuming a 6-car train having a total weight of 240 tons, the total resistance will be 7 200 lb., and the corresponding electric horse-power, assuming a loss of 25% in transmission, would be 1 200, or would necessitate 200 e.h.p. per car. If it is assumed that each car has two 160-h.p. motors, there would be 120 h.p. available for other purposes than speed resistance, if the motors were worked up to their rating. If 20 lb. per ton is taken as the resistance per 1% of grade, the train would be capable of maintaining this speed on a 0.9% grade only. As this grade is far from being excessive in tunnel practice, it is evident that, in a tunnel of this description, the limiting speed is at 45 miles per hour for 6-car trains, and would very likely be lower. Another great difficulty would be met in acceleration, and the impact shock would be enormous.

The last curve on Fig. 4 is calculated for a tunnel 8 miles between air exists, such as a tunnel from Manhattan to Staten Island. It is not known that the formula would be applicable to a tunnel of that length, but it is certain that the resistance would be very high.

Assuming the same train make-up as before (6 cars, total weight 240 tons), and the total power as 1 920 e.h.p., then, at 40 miles per hour, the tractive power is 13 400 lb., or 56 lb. per ton; the calculated resistance is 68 lb., or the train could not reach this speed. At 35 miles per hour the tractive power would be 15 400 lb., or 64 lb. per ton. The limiting speed for a train of this kind in the tunnel, therefore, would be between 35 and 40 miles per hour on the level, working the motors to their capacity.

In a long tunnel of this kind, a factor which would enter into consideration would be the effect of such a high pressure on the ears of the passengers. In tunnels as long as those of the Pennsylvania Railroad at New York this is uncomfortable, but in a tunnel more than seven times as long, this discomfort would be very much more marked.

In connection with the air resistance of long tunnels, it may be of interest to note the results reported from the Simplon Tunnel.*

The electric locomotives used in this tunnel were from the Valtellina

* *Engineering*, Nov. 23d. 1906.

Railroad, and their section is reported as being two-thirds of that of the tunnel, or rather more than the section of the Hudson and Manhattan, which is 56% for iron and 54% for concrete. The weight of the locomotive is 62 tons, and the horse-power is from 900 to 2 300. It appears that about 400 h.p. more is required to haul a train at 70 km. per hour (43.5 miles per hour) through the tunnel than would suffice for it in the open. It was further found that on a gradient of 1 per 1 000, from the summit to Iselle Portal, the locomotive would not run down by gravity alone, but would with a train behind it. The fans installed at the portal are reported to affect the resistance somewhat.

There are five remedies for cutting down this great resistance in long tunnels, where there is no way of making intermediate air exits:

(*a*) Blowing engines;

(*b*) More than one train in the tunnel at once;

(*c*) Wind shields on the trains;

(*d*) Smooth lined tunnels;

(*e*) Increase in area.

(*a*) *Blowing Engines.*—There is no doubt that the installation of blowing engines, or pressure fans, at one end and exhausters at the other, would reduce the air resistance materially, but the cost of the outfit and power would be very high, if the resistance was to be much reduced. On the other hand, the size and cost of the car motors would be correspondingly reduced, and, in some instances, this saving would balance the cost of installation.

(*b*) *More Than One Train in the Tunnel at Once.*—If more than one train is in the tunnel at the same time, the resultant total pressure will not increase in proportion to the number of trains. The impact on entry will be the same on each train, but the total static resistance will be about the same as if only one train was moving the air. In this way the total resistance on each train would be reduced.

(*c*) *Wind Shields.*—Wind shields of different kinds have been used in the open for cutting down the speed resistance of high-speed trains with varying success. In a tunnel the shield would reduce both components of air resistance, the impact as well as the static.

In Irminger's experiments* in towing models, he found that if the

* *Minutes of Proceedings*, Inst. C. E., Vol. CXLVII, p. 276.

resistance to motion of a plane at right angles to the direction of motion was represented by 100, a cone with its apex forward would have 42% resistance. Working from this, assume that a cone is built out at the front of the forward car, so that the angle at the apex is 90°; then, for a Hudson and Manhattan car, the diameter at the base would be 8 ft., and the distance from the apex to the front of the car 5 ft. 8 in. If it is assumed that the volume is the same as before, the volume of air which would be deflected would be 0.707 of the former volume. Then, as will be apparent from the derivation of the formula, the resistance would be cut down by this amount, or the resistance with the shield would be only 70% of that without, which, when compared with Irminger's tests, would seem reasonable. In this cone, however, there would be windows or other recesses or projections, therefore it may be said that only 25%, instead of 30%, would be the saving.

Assuming the same train as before, that is, 6 cars, 40 tons each, and a speed of 45 miles per hour, the resistance offered by a flat car surface, in the open, would be 15 lb. per ton, or an expenditure of 576 e.h.p. A saving of 25% by wind shield would be 144 e.h.p. This saving in power would be quite an item, and the first cost of motor equipment could also be reduced materially.

The saving by wind shield in tunnels would affect both components: the impact, by not deflecting so much air, and the static, by not forcing through the tunnel columns of air of such large section. The net resistance could then be assumed to be 25% of the plane front resistance. Then, for the same train as above, at 40 miles per hour, in a 6 000-ft. tunnel, the electric energy expended by a train having a flat front would be 655, and with a shield, 490, or a saving of 165 e.h.p.

In a 2-mile tunnel, at the same speed, the horse-power would be 860 for a plane front and 643 for a cone, or a saving of 217 e.h.p. For the very long tunnel (8 miles), the power without the shield would be 2 370 h.p., or 395 h.p. per car, and with the shield 1 780 h.p., or 297 h.p. per car, or a total saving of 590 h.p. It would then appear that for very long tunnels the wind shield is highly important, and in some cases might be absolutely essential.

There are several disadvantages in the use of a shield, the principal one being the inconvenience of always having, at the head end of the

train, a coach equipped in this way, though, if locomotives were used, this would be of less importance. The ventilation by the piston action of the train would also be affected, as the volume of air dispelled would not be as great.

(*d*) *Smooth Lined Tunnels.*—The pressure necessary to force air through a duct depends to a great extent on the relative smoothness of its surface; the rougher the surface the more resistance is offered to the flow of air, and hence more pressure is required. This same question—smoothness in tunnel walls—will enter into the train resistance in tunnels, affecting the static component principally.

In the case of iron-lined tunnels, such as those of the Hudson and Manhattan Railroad, Fig. 1, Plate XXXI, there would be, every 2 ft., a flange, 3 in. wide, projecting about 6 in. toward the center of the tunnel, and at the center of each ring the erecting lug projecting above the inside of the iron. The air in passing must impinge on these projections, thus causing eddies and increasing the resistance. The highest velocities are found in the center of the tunnels, between the bench-walls, therefore, the air which actually strikes the walls and is broken up by these projections, is not moving at the greatest speed, and the total resistance due to this cause will not be as high as if the mean velocity of movement was uniform for the whole tunnel section.

The runs on October 7th were made through tunnels of two types of construction—the iron-lined and the concrete. The concrete has a slightly larger sectional area, 6 sq. ft., and the conditions as to air exits are not the same, therefore no direct comparison may be made in regard to the increase in resistance caused by the rougher surfaces.

Tunnel "A," starting a short distance west of Morton Street and extending for 3 500 ft., is an iron tunnel, lined with concrete in such a manner that no flanges or other projections extend beyond the concrete, and its section is essentially the same as the iron, 90 sq. ft. In some of the previous tests, runs were made through this tunnel, and the resistances were compared with those from the standard iron tunnels, where the other conditions as to length and air exits are as near alike as possible. This comparison would tend to show that the saving in total air resistance, due to the lining, was 20 per cent. This figure is only approximate, because the runs, of necessity, could not be made in the same tunnel, therefore other factors than the condition of the surfaces enter. This 20% saving does not appear to be too high,

so that it is reasonable to suppose that there would be at least a 20% saving in power consumption by lining the tunnel.

Assuming a 2-mile tunnel with iron lining and the same make-up as before, let the average speed for the trip be 30 miles per hour, then the average speed resistance would be 13 lb. per ton, and the average power per trip 330 e.h.p. Assume that for 10 hours, 12 trains per hour are moved, for 8 hours 4 trains per hour, and for 6 hours 2 trains per hour, or 164 train movements per day per tunnel. This would be the expenditure of 2 720 kw-hr. per day of 24 hours, and at $\frac{3}{4}$ cent per kw-hr., the cost per day would be $20.40 for speed resistance alone. Now, if the tunnel was lined with concrete, 20% of this could be saved, or $4.00 per day, and this would be the interest at 6% on $24 400. Then, in order to be practicable, the cost of the extra lining should not exceed this amount; but it would be impossible to line an existing tunnel of this length for such a sum, so that, unless the tunnel was lined with concrete for some other reason, there would not be saving enough to balance the extra cost.

A combination of (*c*) and (*d*), or wind shields in a concrete tunnel, would mean a saving of 25% for the former and 20% for the latter, or a net saving of 45 per cent. Then, if (*a*) was used, this would mean, perhaps, 5% more, or 50% in all. Therefore, a combination of concrete-lined tunnels, with fans or blowing engines of large capacity at the ends, and the use of trains with wind shields, would appear to give a great saving in power consumption and first cost of electric equipment; and, in very long tunnels, it would give more satisfaction to the traveling public, because of the elimination of the pressure on the ears of the passengers.

(*e*) *Increase in Tunnel Section.*—As mentioned before, the cross-sectional area of the tunnel is the controlling factor in the air resistance offered to the train. As the section is increased, the resistance falls off, and approaches that found in the open. On account of mechanical clearances, the tunnel section could be reduced very slightly from that given, so that no calculation will be attempted for small areas.

Assume that the diameter of the tunnel is increased 1 ft., or from 16 ft. 7 in. to 17 ft. 7 in. The ratio of clearance to possible area in the standard tunnel is 74%; then for the 17 ft. 7-in. tunnel, the clear area would be 187 sq. ft. It is safe to say that, as the impact resist-

ance depends on the quantity of air which strikes the car and is deflected, and as this volume depends on the area of the tunnel, the impact resistance would vary inversely as the section. Then, as the area of the standard bore is 86% of the assumed one, the impact in the latter case would be but 86% of the former, or 14% saving.

An examination of the formula for static resistance shows that any change in the diameter of the tunnel will affect both terms in the denominator—the K and the d. The K will change with the area, as this term modifies the V, or takes into account the difference between the train speed and the air velocity. It is reasonable to suppose that the K will increase in the same ratio that the area increases, for the volume of air which is pushed ahead of the train, and hence the velocity, will depend on the diameter of the tube.

The d, or pneumatic diameter, will also affect the static resistance, for, as it increases, the pressure will diminish. If the d is disregarded, then the decrease in static resistance will be in the same proportion as the impact. Then, in the case assumed, the total air resistance will be 86% of that in a standard tunnel.

From (d) it is seen that it would cost $20.40 per day for air resistance alone; then, if the saving is 40%, $2.85 per 24-hour day would be saved, or the interest at 6% on $17 300; but, if the extra foot is added for reducing resistance only, the $17 300 will have to cover the extra cost. A ring of the standard tunnel will weigh 5 670 lb. per lin. ft.; then, if the segments were no heavier, the addition would mean 340 lb. more per foot of tunnel, or, for the whole length, 3 590 000 lb. If the cost of the extra metal, grout, cement, labor, etc., was only 3 cents per lb., the total additional cost would be $107 000, or more than six times the saving in resistance. Any further increase in diameter would increase the extra cost in a much higher ratio than it would decrease the resistance cost, therefore, it would not be practical to increase the diameter for this purpose alone.

If, in place of single-track tunnels, tubes or subways of two or more tracks were used, the resistance would be materially reduced, but the ventilation due to the piston action of the train, would be seriously affected.

A train entering such a tunnel would displace and push ahead of it a volume of air which would be considerably smaller than that found in these tests, the larger part of the air passing back at the

sides of the train and not being moved forward any great distance. This condition would exist until a train, moving in the opposite direction, entered the other end of the tunnel, when a counter current would be set up which would strike the first current, and the result would be a group of eddies.

In tunnels where there are two and four tracks, as in the Interborough Subway, and the traffic is very dense, there must be a considerable expenditure of energy due to these eddies, and if the outlet stations were farther apart, this would be still more marked. This action not only causes increased resistance, though probably not as much per train as in the single-track tubes, but eliminates the piston ventilation of the train, the air being shoved from side to side and given rotary motion instead of being expelled. This eddying and buffeting of the air permits it to absorb a large amount of heat from the operation of the trains, causing an increase in the temperature for the whole tunnel.

To ventilate by the action of the trains such a two- or four-track subway, in which trains are operated in contrary directions, appears to be practically impossible, and the ventilation of such tunnels must depend on the installation of fans, operated independently, which will remove the air at short intervals. The number and capacity of such fans involves a very heavy item, both in the first cost of installation and in the cost of operation. The enormous volume of air which is displaced and moved forward by the action of a train in a tube tunnel, such as described in the foregoing experiments, insures thorough and proper ventilation of the tunnel, provided the whole or a large portion of the air moved forward by the trains is removed entirely from the tunnel at certain fixed points. This has been the principle on which the ventilation of the Hudson and Manhattan tubes has been laid out, as has been described in the technical journals from time to time.

In these experiments it may be noted that the actual cross-section of the end area of the car is assumed as the area affecting the impact pressure. It is probable that this is not strictly the case, as there is undoubtedly a zone immediately exterior to the car which by frictional resistance draws the air along with it for a certain depth outside of the net structure of the car. It is practically impossible to determine the depth of this moving but gradually reducing zone of air; it would vary with its location along the body of the car, and in

differing degree along the entire length of the train; consequently, for the practical purpose of the application of the results of these experiments, it is simpler to assume that the impact is transmitted on the net cross-sectional area of the actual car construction.

All the experiments and the working up of the results of these experiments have been carried out under the direction of George D. Snyder, M. Am. Soc. C. E., Principal Assistant Engineer, and by Mr. B. S. Murphy, who has been Assistant Engineer to the writer on the mechanical work throughout the construction of the plant and tunnels of the Hudson and Manhattan Railroad Company.

APPENDIX.

Train Resistance Tests, October 7th, 1911.

Air Resistance in Open.

From the assumptions made on page 374, we can write:

$$P : D\,Q :: (V_s - U_s) : g$$

or

$$P = D\,Q \left\{ \frac{V_s - U_s}{g} \right\} \ldots\ldots\ldots\ldots (1)$$

in which P = Total pressure on the car, in pounds;
V_s = Original velocity of jet, in feet per second;
U_s = Velocity of train, in feet per second;
g = Acceleration due to gravity = 32.16;
Q = Quantity flowing, per second, in cubic feet;
D = Density of air, in pounds per cubic foot;
and $D\,Q$ = Weight of air flowing in a second.

As the car is assumed to be at rest, $U_s = 0$. Then Equation (1) becomes

$$P = D\,Q \frac{V_s}{g} \ldots\ldots\ldots\ldots (2)$$

Let V = equal miles per hour, then

$$V_s = \frac{5\,280}{3\,600} V \ldots\ldots\ldots\ldots (3)$$

and $Q = A\,V_s$

where A = sectional area of the car, in square feet.

This would be true if the quantity deflected by the train varied directly as the sectional area, but this is not so, so this term will become

$$Q = K\,A\,V_s.$$

Where K is a variable, depending on the speed, substituting the value of V_s, in terms of V, gives

$$Q = K\,A \frac{5\,280}{3\,600} V \ldots\ldots\ldots\ldots (4)$$

Substituting these values of Equations (3) and (4) in Equation (2) gives

$$P = 0.0672\;D\;K\;A\;V^2 \ldots\ldots\ldots\ldots (5)$$

for an air temperature of 52° Fahr.

$D = 0.0776$, and, as $A = 90$ sq. ft., Equation (5) gives:

$$P = 0.468\;K\;V^2 \ldots\ldots\ldots\ldots (6)$$

This formula was then solved for values of K by substituting the values of P from the curve, and these were plotted against the corresponding speeds. When these values are plotted, the resultant figures approach the shape of the hypothenuses of two right-angled triangles, the apex of each being at 32 miles per hour.

The formulas for the curves are:

Up to 32 miles per hour:

$$K = 1.772 - 0.0382\ V.$$

Greater than 32 miles per hour:

$$K = 0.0182\ V - 0.03.$$

Substituting these values in Equation (5) gives, for the general expression for pressure:

Up to 32 miles per hour:

$$P = 0.0672\ D\ A\ V^2\ (1.772 - 0.0382\ V) \quad \text{.................(7)}$$

Greater than 32 miles per hour:

$$P = 0.0672\ D\ A\ V^2\ (0.0182\ V - 0.03) \quad \text{.................(8)}$$

Substituting the values of K in Equation (6):

Up to 32 miles per hour:

$$P = 0.468\ V^2\ (1.772 - 0.0382\ V) \quad \text{.....................(9)}$$

Greater than 32 miles per hour:

$$P = 0.468\ V^2\ (0.0182\ \ V - 0.03) \quad \text{.....................(10)}$$

Air Resistance, Iron Tunnels.

Impact.—(Page 379.) Following the same reasoning as for impact in the open, we have

$$P = D\ Q\ \frac{V_s}{g} \quad \text{.........................(2)}$$

Now, $Q = V\ A$; but, from the velocity tests, it is known that the volume of the air deflected is not the product of the cross-sectional area of the car by the train speed, or that the A is not the same as the cross-section of the car. The area corresponding to the displaced volume was calculated and plotted against the train speed, and the resultant curve was found to be a straight line between the available speed limits of from 18 to 28 miles per hour. The equation for this line is

$$A_a = \frac{28 - V}{0.3704} + 115 \quad \text{....................(16)}$$

in which A_a = apparent sectional area of the deflected air current at a velocity equal to that of the train.

$$\text{Also, } V_s = \frac{5\ 280\ V}{3\ 600}$$

$$\text{and } Q = V_s \left\{ \frac{28 - V}{0.3704} + 115 \right\} \text{ from Equation (16)}$$

$$\text{or, } Q = \frac{5\ 280}{3\ 600}\ V \left\{ \frac{28 - V}{0.3704} + 115 \right\}$$

Substituting these values in Equation (2) and simplifying, gives

$$P = D\ V^2\ (12.75 - 0.1809\ V) \qquad (17)$$

And, if the temperature of the air is 65° Fahr.,

$$D = 0.0761.$$

Then, $P = 0.0761\ V^2\ (12.75 - 0.1809\ V)$ .... (18)

Static.—(Page 379.) The second component of the total air resistance, or the static, would be governed by the same formula as used for the flow of air in ducts, or

$$p = \frac{L\ V_s^2}{K\ d} \qquad (19)$$

in which p = Corresponding resistance, in ounces per square inch;

V_s = Velocity of air, in feet per second;

d = Pneumatic diameter, in inches $= \frac{\text{Area of Duct} \times 4}{\text{Perimeter}}$;

L = Length from front of train to air exit, in feet;

and K = Constant.

Area of tunnel = 160 sq. ft.;

Perimeter = 605 in.;

d = 152 in.;

P = Total static pressure on car.

Then, as the area of the car is 90 sq. ft.,

p = 0.00123 P.

V = train speed, in miles per hour.

Then, $V_s = 1.47\ V$.

Substitute these values in Equation (19),

$$P = 11.55\ \frac{L\ V^2}{K} \qquad (20)$$

The lengths of the iron tunnels in which the tests were made were such that three lengths, or values of L, may be taken, namely, 2 000, 4 000, and 6 000 ft. The total air resistance found for each of these lengths is plotted on Fig. 6. The distance of each of these curves above the impact line will be the static resistance. Values of P were then taken from the curves and substituted for P in Equation (20) for the respective values of L, and K was solved. These values of K were averaged, and the result was 56 300. Then, substituting K = 56 300 in Equation (20), gave

$$P = 0.000205\ L\ V^2 \qquad (21)$$

Resistance, Concrete Tunnels.

Impact.—(Page 380.) As mentioned previously, the velocity tests in the concrete tunnels were a failure, as the part of the total air deflected is not known, but, as the cross-sectional area of the concrete tunnels is 166 sq. ft. and that of the iron tunnels 160 sq. ft., it will

be assumed that the slip is higher, in the ratio of $\frac{160}{166}$, or that the volume which affects impact is only 96% of that in the iron. Therefore, modifying Equation (18),

$$P = 0.96 \times 0.0761 \, V^2 \, (12.75 - 0.1809 \, V)$$

or

$$P = 0.0745 \, V^2 \, (12.75 - 0.1809 \, V) \qquad (24)$$

Static.—(Page 380.) Using the same equation as for iron tunnels, Equation (19), or

$$p = \frac{L \, V_s^2}{K d},$$

the area of the tunnel = 166 sq. ft., the perimeter = 608 in., and d = 157 in.

Substitute the values from Equation (19):

$$P = 11.2 \, \frac{V^2 \, L}{K} \qquad (25)$$

The value of K was worked out by substituting different values of P from the curve for a 3 000-ft. tunnel, from which K was averaged. The result was:

$$K = 700\,000.$$

Substituting this value in Equation (25) gives

$$P = \frac{11.2 \, V^2 \, L}{700\,000} \qquad (26)$$

This large increase in the value of K over that used for iron tunnels is not all due to the smoother surface, but depends also on the air exits.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE APPRAISAL OF PUBLIC SERVICE PROPERTIES AS A BASIS FOR THE REGULATION OF RATES.

By C. E. Grunsky, M. Am. Soc. C. E.

To be Presented June 5th, 1912.

Introduction.

It is the purpose of this paper to make clear the fact that appraisals of public service properties for rate-fixing purposes can be made, with advantage to all parties concerned, without deducting anything from the properly invested capital for depreciation. Incidentally, it will be pointed out that depreciation must, and how it should, be taken into account in estimating net earnings; that appreciation should be regarded as a reinvestment of earnings; and that there is and can be no definite basis for such elements of value as "going concern" and the like, unless operations are conducted under a restrictive franchise, that is, unless the franchise frees the public service corporation from outside control of its rates. No apology need be made for the elementary treatment of parts of the subject.

The appraisal of public service property for various purposes, such as taxation, regulation of rates, purchase, and limitation of indebtedness is receiving attention by many engineers and financial experts at the present time.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Ideas in the matter of valuation, both in relation to what should be included in the valuation and to the valuation itself, are so diverse that a few words about the fundamental principles which should control when the appraisal of a public service property is to serve as a basis for fixing the rates to be charged for the service, are now offered in the hope that what is presented may aid in unifying methods of computing the desired earnings and in overcoming some of the difficulties into which the Courts are leading the experts.

The definite programme herein indicated for dealing with depreciation and amortization is the outcome of the writer's professional employment in California on appraisals, representing, at various times, the rate-payers, and, at other times, the owners of public service properties.

No attempt will be made to apply the conclusions reached to valuation for other purposes than the regulation of rates, nor to valuations in those cases in which special privileges have been granted, in which, therefore, the franchises are in the nature of an agreement or contract. Neither is it proposed to deal with any cases out of the ordinary, such as those in which the owner of a property was aided by bond issues, land grants, and the like. The main purpose will be kept in view of presenting a clear analysis of the fundamental problem so that an understanding may be had of the principles which should prevail whenever an appraisal is made for rate-regulation purposes.

The Law in California.

The following is from the Constitution of the State of California (in effect January 1st, 1880):

"The use of all water now appropriated, or that may hereafter be appropriated, for sale, rental or distribution, is hereby declared to be a public use and subject to the regulation and control of the State, in the manner to be prescribed by law; provided, that the rates or compensation to be collected by any person, company or corporation in this State for the use of water supplied to any city and county, or city or town, or the inhabitants thereof, shall be fixed annually by the Board of Supervisors, or city and county, or city or Town Council, or other governing body of such city and county, or city or town, by ordinance or otherwise, in the manner that other ordinances or legislative acts or resolutions are passed by such body, and shall continue in force for one year and no longer. Such ordinances or resolutions shall be passed in the month of February of each year, and take effect on the first day of July thereafter.

"The right to collect rates or compensation for the use of water supplied to any county, city and county, or town, or the inhabitants thereof, is a franchise, and cannot be exercised except by authority of and in the manner prescribed by law.

"In any city where there are no public works owned and controlled by the municipality, for supplying the same with water or artificial light, any individual, or any company duly incorporated for such purpose under and by authority of the laws of this State, shall, under the direction of the Superintendent of Streets, or other officer in control thereof, and under such general regulations as the municipality may prescribe for damages and indemnity for damages, have the privilege of using the public streets and thoroughfares thereof, and of laying down pipes and conduits therein, and connection therewith, so far as may be necessary for introducing into and supplying such city and its inhabitants either with gas light, or other illuminating light, or with fresh water for domestic and all other purposes, upon the condition that the municipal government shall have the right to regulate the charge thereof."

The charter of the City and County of San Francisco (in effect January 8th, 1900) mentions, among the powers of the Supervisors:

"To fix and determine by ordinance in the month of February of each year, to take effect on the first day of July thereafter, the rates of compensation to be collected by any person, company or corporation in the City and County, for the use of water, heat, light or power, supplied to the City and County or to the inhabitants thereof, and to prescribe the quality of the service."

General Remarks.

The value of a revenue-producing property is determined ordinarily by its earning capacity; but this earning capacity, when it is to be used as a basis for valuation, must itself be determined with proper consideration of all attendant circumstances. It is not enough to compare receipts with current expenditures when estimating net returns. Account must be taken of the useful life of the property, because in order that the property may be kept at a standard serviceability, parts, or all of it, must be replaced from time to time, unless indeed it happens to be of a character similar to real estate, having for all practical purposes a perpetual life. Such circumstances as appreciation in value which may arise from an advance of real estate values, or from other causes, must also be taken into account.

Knowing the earning capacity and the ordinary interest return

expected from an investment, it becomes an easy problem in mathematics to capitalize earnings, it being understood that no necessary expenditure, present or prospective, has been overlooked, and that, in estimating useful life and the requirements of an amortization or a replacement fund, every factor, such as ordinary deterioration, inadequacy, and obsolescence due to advance in the arts, shall have been given due weight and consideration.

In the case of properties, however, the earnings of which are subject to regulation, an element of uncertainty concerning the amount of earnings may be introduced, rendering it impossible to use earnings as a basis for computing value.

Cases do occur in which franchises are exclusive, and in which rates for services rendered remain operative for long periods of time, in which, therefore, even under a system of rate regulation, it is possible to estimate earnings for long future periods and in which the earnings are determinable with sufficient precision to be used, in some measure at least, in determining value; but this is not so in California. There the system of annual rate fixing prevails, and the maximum rates allowed are presumed to be fixed so that under them there may be a fair return to the corporations on the value of the properties actually in use in rendering the service. Perhaps the use of the term, "value," in this connection is unfortunate, because it is not clear why "value," as ordinarily defined (which is not always synonymous with capital reasonably and properly invested), should be made the criterion of allowable earnings. It is reasonable to assume that the term, "value," in connection with the fixing of rates, has been used without prejudice to the rights of the owner of a public service property, and, therefore, some note will be taken in what is here presented of value as it may appear from different standpoints.

It is not necessary to state that, in a critical analysis of earnings, which go in part to an amortization fund and are in part distributable as a return on the investment, the rate of interest taken into account should be the same throughout. When it shall have been determined in any particular case what the earnings must be to yield the same rate of return as could be obtained from ordinary safe investments, then any desired addition as compensation for having undertaken the operation of the public service property, or for unusual risk, may be added.

Useful Life, Value, Depreciation, and the Amortization Fund.

The general presentation of the problem will be simplified by assuming that the actual useful life or service of a plant, or part of a plant, conforms in every case exactly to its expectancy. That this is not in reality the case, and how it affects the conclusions which otherwise would be reached, will be referred to later.

In the presentation of the subject, this assumption has been strictly adhered to, and the rate of interest uniformly applied is 4% per annum.

Take the case of a plant, every part of which has a life of 20 years, all constructed at one time and owned by a prudent owner who sets apart, as an amortization fund, each year $0.03358 for every dollar invested therein at an interest of 4% per annum. If the plant is one which will actually net 4%, then the apparent excess of the earnings, including amortization, over expenses, should be $4 + 3.36 = 7.36\%$, and the owner, in estimating the price at which he can sell without loss at the end of any period, as, for example, at the end of 10 years, would figure as follows (for each $100 of original investment):

Investment	$100.00
In the amortization fund: being the amount of a 10-year annuity of 3.358% at 4% interest..	40.30
Remaining value..................................	$59.70

A prospective purchaser would figure that the plant should be worth at least as much as the annuity of 3.358% would amount to in the remaining years of the plant's life.

The amount of a 10-year annuity of $3.358 is $40.30, and to this amount he would add a sum determined from the excess earnings of the plant over a net earning of 4% during its remaining life on the part of the value which he has estimated, as explained, on the amortization or retirement fund basis.

The earnings being based on 4% of the originally invested capital, the increment of value covered by the amortization fund being $40.30, on which 4% is $1.609, for 10 years there will be earned an additional $2.391 per annum, of which the present value is $19.40. The purchaser, therefore, will conclude that he can invest with assurance of a 4% net return, $40.30 + $19.40 = $59.70.

Of course, the same conclusion could have been reached by determining the present value of the earnings treated as an annuity of \$7.358 for the remaining 10 years, which at 4% per annum, is \$59.70.

At the end of 10 years, the original owner, keeping for his own use the money in the replacement fund, will be satisfied to sell at \$59.70. The purchaser, content in this case with the assumed rate of interest of 4%, will be willing to pay this \$59.70, because, at the end of the plant's useful life, he will have recovered his investment with 4% interest compounded annually. He will then be under the necessity of replacing the plant, making a new investment of \$100, as the original owner would have been if he had remained in possession.

During the entire 20 years of usefulness the plant has been rendering adequate service. The sufficiency of the service is independent of, and bears no relation to, the useful life of the plant, nor to the fact that it was gradually deteriorating. During all periods of the plant's life, the depreciation of its physical elements was offset by the accumulation in the amortization fund.

Of course, it cannot be known just how, nor at what rate, the actual deterioration of a plant takes place. This may be rapid at some period of its life, and slow at another, but as it is supposed, at all times during its life, to be adequately performing the service expected of it, this rate of decay is entirely immaterial.

In other words, the amortization may be determined without regard to the physical condition of a plant at any period of its life, provided, of course, that the plant fulfills the requirements of adequate service at all times of its life. For this reason it has become convenient to consider the actual, or the theoretical, accumulation in an amortization fund as the measure of plant depreciation with a consequent interchange of terms, which has led to a quite general use of the term, "depreciation," when designating the retirement of invested capital.

There is a clear distinction between amortization and replacement. The amortization deals with the repayment of the original investment. This may be in installments in uniform or unequal annual amounts, or in a lump sum at the end of useful life. The replacement may mean the substitution of a new identical plant, but at a cost dependent on new conditions, new prices of labor and material, or it may mean the substitution of new devices rendering equivalent service. In

either event the replacement may be at a greater or less cost than the original cost, with, therefore, a corresponding increase or decrease of capital invested. The expenditure for replacement is amortization only to the extent that it retires capital already invested.

Perhaps, in referring to the worn-out part, the term "retirement" would be more applicable. In the sense in which "replacement" is used throughout this paper, except when otherwise explained, it is that part of the new investment in permanent construction, which is equal to the capital theretofore invested in the parts which are discarded and replaced. Expenditures for new parts of a plant, which take the place of old parts which are retired for any cause, should be charged to replacement only to the extent of capital thus retired. Any excess of the expenditure for replacement over the cost of the discarded part of a plant should be treated as an addition to, and any less cost as a deduction from, the invested capital. The term, "replacement," used in the sense of retirement of invested capital, deals with the cost of the replaced part and not with that of the new equivalent installation. Theoretically, the amount which should go into an amortization fund should be estimated on the basis of invested capital or cost, and actual replacement should be made up out of this fund as far as the same may prove adequate.

Returning again to the case of the supposed valuation by a seller and by a purchaser of a plant with a 20-year useful life, at the end of a 10-year period; there is no need of assuming that an amortization fund has actually been created. In the case of both the original owner and a purchaser, the amortization annuity, instead of being actually placed in funds, may be otherwise invested.

When the owner of a plant which is yielding 4% per annum and nothing for amortization, sets apart, out of the 4%, an annual amount, also bearing interest at 4%, to meet its replacement at the end of the plant's useful life, he has invested not only the original cost of the plant, no part of which comes back to him in the annual 4% return, but also a gradually increasing sum which in the life of the plant will become adequate to replace it. At the end of the plant's usefulness, after replacing it with a new one, the total investment will be doubled without any increase of earning capacity, and the owner will have in effect lost his original investment.

It follows from this that a return of 4% per annum, without any-

thing for amortization, on an investment in a perishable plant, when money is worth 4%, is inadequate. The excess of earnings over expenditures must be at least equal to the current interest rate on safe money investments plus an increment depending on the useful life of the plant. This increment must be such that, within the life of the plant, it will return to the owner his original investment.

Had the owner borrowed money for the construction of the plant and were he paying interest on the borrowed money at 4%, this fact would be self-evident. The 4% earnings would then be required to meet interest payments, and at the time when his plant has reached the end of its life and must be replaced with a new one, he would find himself, not only in debt for the original plant, but would have to duplicate the indebtedness for the replacement.

The amortization increment is ordinarily expected to appear in the earnings as that sum which, at compound interest during the life of the plant, will be adequate to retire the original investment.

To illustrate these points further, let it be supposed that ownership is represented by capital stock of a corporation. If the plant owned by the corporation earns just enough to net 4% without any allowance for amortization, the stock which at the outset was worth 100% will gradually decrease in value until, at the end of the plant's usefulness, it will be worth nothing.

The situation is quite different when the earnings net 4% plus an annual amortization increment. In this case, the stockholder receives 4% each year, and the amortization fund grows as the plant depreciates in value. The stock remains at par from the beginning to the end of the plant's usefulness, and the money in the fund at the end of the period is available either for distribution to the stockholders, being a return of the money advanced by them, or for reinvestment in a new plant to replace the original one.

Should a sale be made at any time while the plant is in service, the valuation of the plant would be made, as already explained, with due allowance for its depreciation, and this value being recognized by a purchaser and the price paid, there would again be 100% available for distribution to the stockholders, the deficiency of the selling price being made up by the accumulation in the amortization fund.

In the case of inadequate earnings, the valuation of the plant by a purchaser would be at all times less than the value determined by

deducting depreciation; in the case of adequate earnings the valuation would be, as already explained, capital invested (or the replacement cost) less depreciation. Yet, in either case, amortization being computed in the ordinary way for the full expectancy of the plant, the only fair valuation for rate-fixing purposes, in a spirit of fairness to both owner and rate-payer, would be a valuation at par without any deduction for depreciation.

Theoretically, then, a part of the earnings each year should be placed in an amortization fund as a repayment of capital invested, and this may be used for the replacement of the plant when it has reached the end of its life.

The accumulation of an amortization fund to be thus used, however, while theoretically sound policy, is a measure not always adopted in actual practice, particularly when the properties owned are of a complex character—when they are made up of numerous parts of various periods of probable usefulness. Municipalities, State, and National Governments, do not set apart funds for the replacement of worn-out or antiquated buildings, parts of water-works, street pavements, sewers, and the like, until occasion arises. They do not maintain funds at interest out of which to reconstruct their public works. The sinking fund required to retire bonds which may have been issued to construct these works originally, must not be confounded with a replacement fund. The one may be necessary to pay for the works in the first instance, the other to maintain them for all time. The annual contribution to the sinking fund is a partial payment for the original work. The contribution to a replacement fund, in the case of a plant free from debt which is to serve without time limit, is for the purpose of perpetuating the work, because in that case the replacement fund as far as it will go, or as far as it is required, will be used for making replacements.

Though it may be difficult to make satisfactory forecasts with reference to necessary reinvestments to replace discarded parts of a plant, the requirements for amortization, being based on cost, are usually readily determinable with some degree of precision.

Thus far, the plant considered is assumed to have been constructed and put into use all at once, and is of such a character that all its parts have the same life. The same principles will apply when a plant

is made up of many elements or parts having various periods of usefulness.

It is again possible to determine for each part the amortization fund or the replacement fund annuity, and from the annuities thus determined to estimate what the minimum earnings should be to prevent loss.

The following problem presents itself: In the case of a plant of gradual development, but of full growth and mature age, the useful life of all the parts of which is n years, it is desired to know what amount is in the amortization fund at any time, that fund being assumed to receive such an increment at the end of each year that, during the life of the several parts of the plant, this annuity, with interest, will amount to the original cost of these parts.

Being composed of a large number of elements—each year having added new ones—the addition to it per year will be taken at one-nth of the total plant as it stands at the end of the nth year.

For each dollar invested in the first year, there will be \$1 invested in each succeeding year, and for each dollar thus invested there will be n dollars of total investment.

Let i represent the rate of interest per year, and a represent the annual contribution to the amortization fund for each dollar invested.

Assume this to be available at the end of each year.

Then na will be, after n years, the annual contribution to the amortization fund for each dollar invested.

Let m represent any number of years greater than n.

During the first n years, after beginning the construction of the plant, there will be no replacements, and the amortization fund continues to grow. At the end of the nth year the replacement requirement, assuming permanency in character and cost, will be \$1 for each dollar of annual investment, and this replacement requirement will continue at this rate thereafter.

At the end of the nth year the amortization fund will contain:

For each dollar invested the first year:

$$a\left(\frac{100+i}{100}\right)^{n-1} + a\left(\frac{100+i}{100}\right)^{n-2} + \ldots + a \text{ dollars}$$

Or,

$$\frac{100\,a}{i}\left[\left(\frac{100+i}{100}\right)^{n} - 1\right] \text{ dollars}$$

For each dollar invested the second year:

$$a\left(\frac{100+i}{100}\right)^{n-2} + a\left(\frac{100+i}{100}\right)^{n-3} + \ldots + a \text{ dollars}$$

Or,

$$\frac{100\,a}{i}\left[\left(\frac{100+i}{100}\right)^{n-1} - 1\right] \text{ dollars}$$

For each dollar invested the nth year: a dollars less the \$1 replacement requirement at the end of the nth year.

Therefore, the total amount in the sinking fund at the end of the nth year, after deducting the \$1 replacement requirement of that year:

There will be in the sinking fund for each dollar invested:

At the end of the $(n+1)$st year:

$$S_{n+1} = S_m\left(\frac{100+i}{100}\right) + n\,a - 1.$$

At the end of $(n+2)$d year:

$$S_{n+2} = S_n\left(\frac{100+i}{100}\right)^2 + (n\,a - 1)\left(\frac{100+i}{100}\right) + n\,a - 1.$$

At the end of the $(n+3)$d year:

$$S_{n+3} = S_n\left(\frac{100+i}{100}\right)^3 + (n\,a - 1)\left(\frac{100+i}{100}\right)^2 + (n\,a - 1)\left(\frac{100+i}{100}\right) + n\,a - 1.$$

And so on, and at the end of the mth year:

$$S_m = S_n\left(\frac{100+i}{100}\right)^{m-n} + (n\,a - 1)\left(\frac{100+i}{100}\right)^{m-n-1} + (n\,a - 1)\left(\frac{100+i}{100}\right)^{m-n-2} + \ldots\ldots + n\,a - 1.$$

Substituting the value of S_n and summarizing the series:

$$S_m = \frac{10\,000\,a}{i^2}\left[\left(\frac{100+i}{100}\right)^{m+1} - \left(\frac{100+i}{100}\right)^{m-n+1} - \frac{n\,i}{100}\left(\frac{100+i}{100}\right)^{m-n}\right] - \left(\frac{100+i}{100}\right)^{m-n} + \frac{100}{i}\left[\frac{(100+i)^{m-n} - 100^{m-n}}{100^{m-n}}\right](n\,a - 1).$$

In this form the formula is convenient for use, being applicable to any value of n and any rate of interest.

For the interest rate of 4% per annum, that is, for $i = 4$, the formula becomes:

$$S_m = \frac{a}{0.0016}\left[1.04^{m+1} - 1.04^{m-n+1} - 0.04\,n\,(1.04)^{m-n}\right] - 1.04^{m-n} + \frac{1.04^{m-n} - 1}{0.04}\,(na - 1).$$

For $m = n$, this formula becomes:

$$S_n = \frac{a}{0.0016}\,(1.04^{n+1} - 1.04 - 0.04\,n) - 1.$$

Applying the foregoing formulas to various periods of life, but adhering to an interest rate of 4%, the following amounts in amortization funds at various times are to be noted:

For a plant of full growth, all parts of which have a useful life of 5 years: $n = 5$, $a = 0.1846$, and the total invested capital is equal to five times the annual investment.

Years.	Amount in amortization fund for each $1 of annual investment.	Amount in amortization fund in percentage of total investment.
At the end of 5	$1.92	38.4
" " " " 10	1.93	38.6
" " " " 15	1.92	38.4
" " " " 20	1.92	38.4

For a plant of full growth, all parts of which have a useful life of 10 years: $n = 10$, $a = 0.08329$, and the total invested capital is equal to ten times the annual investment.

Years.	Amount in amortization fund for each $1 of annual investment.	Amount in amortization fund in percentage of total investment.
At the end of 10	$4.17	41.7
" " " " 15	4.18	41.8
" " " " 20	4.18	41.8
" " " " 30	....	....
" " " " 40	4.18	41.8
" " " " 80	...	...

For a plant, all parts of which have a useful life of 20 years: $n = 20$, $a = 0.3358$, and the total invested capital is equal to twenty times the annual investment.

Years.	Amount in amortization fund for each $1 of annual investment.	Amount in amortization fund in percentage of total investment
At the end of 20	$8.21	41.1
" " " " 30	8.20	41.0
" " " " 40	8.19	41.0
" " " " 80	8.21	41.1

For a plant of full growth, all parts of which have a useful life of 40 years: $n = 40$, $a = 0.01052$, and the total invested capital is equal to forty times the annual investment.

Years.	Amount in amortization fund for each $1 of annual investment.	Amount in amortization fund in percentage of total investment.
At the end of 40	$14.47	36.1
" " " " 60	14.40	36.0
" " " " 80	14.43	36.1

In the foregoing mathematical analysis, a plant has been assumed which has already reached an age exceeding the useful life of its parts, and has reached its full growth.

The same formulas will apply in the case of any plant of mature age and gradual growth, even when the growth is still being extended, because in this special case the plant may be regarded as made up of two groups of parts, one embracing all those having an age of n years or less, and the other those parts which are more than n years of age, and for both these groups the formulas apply.

It is noteworthy, in the assumed case of a plant of full growth made up of numerous parts, that the amortization fund should bear a nearly uniform relation to capital invested, whatever the life of the plant may be. For such a plant constructed progressively, all parts of which have a useful life of 5 years, the amortization fund will, at any time after 5 years, contain an amount equal to about 38% of the cost; for a similar plant with a 20-year life, 41%; and for a similar plant with a 40-year life, 36 per cent.

The accumulation, therefore, in amortization funds, under certain hypothetical conditions, when plants are of progressive growth and mature age and are composed of numerous parts, at 4% interest, amounts to about 40% of the invested capital. In reality, however, there is never absolute agreement between the actual useful life of every part of the plant and its expectancy. The formulas are never strictly applicable. The requirements for replacement may begin long before the expectancy is attained, and if met from the amortization fund will check its growth.

The non-existence of a fund in the full amount indicated by mathematical and theoretical considerations, therefore, does not always show that it has been distributed as profit, nor yet that

there has been an intentional waiver of the right to have the earnings cover a fair amortization allowance.

Furthermore, if the annual amortization increment is immediately applied in repayment of invested capital, the same no longer bears interest. Treated as an annuity, interest may be compounded only as long as the fund remains practically in escrow for its intended purpose, that is, for complete retirement at the end of the useful life of the plant. Interest ceases to accumulate the moment the fund is applied to retire the investment in whole or in part. Consequently, if the amortization be determined from amortization tables based on expectancy, and be covered by the earnings from year to year, even though the amortization increment as earned be reinvested in the property, it cannot rightfully be classed as a repayment of invested capital until the end of the period of expectancy. If so applied at any earlier date, a new amortization annuity, based on the remaining life, must be computed.

If, nevertheless, the amortization annuity as originally determined be deducted from the investment from year to year, the result will be incomplete amortization. In the case of a 40-year life, the amortization of the invested capital would be only \$42.08 of each \$100, and there would still remain \$57.92 to be made good.

These facts make clear the point which is to be emphasized, that whenever amortization is based on annuities bearing compound interest, the appraisal for rate-fixing purposes must be of the entire investment without reduction for depreciation.

The foregoing mathematical demonstration that the accumulation in an amortization fund for a plant of mature age should amount to a considerable sum, confirms a conclusion which can be reached in a more direct way.

In the assumed case of a plant which has a life of n years, and of which one-nth has been constructed each year, after n years there will have to be replaced one-nth thereof each year. Because the annual investment in the installation has been uniform, there will be for each dollar invested per year, a total investment of n dollars.

The annual replacement after n years, for each dollar annually invested, will be \$1. If now the annuity to replace the several parts of the plant in n years is a for each dollar of the annual investment, then after n years, the annual amount received as annuity will be $a\,n$,

and this will fall short of meeting the actual expenditure by an amount expressed by $(1 - a\,n)$ which, at 4% per annum, is the interest on $\frac{100\,(1 - a\,n)}{4}$ dollars; or, expressed in percentage of the cost, is $\frac{100^2\,(1 - a\,n)}{4\,n}$ per cent. of the total investment in the plant.

For a plant not subject to further growth, with a uniform useful life of all its parts, and constructed progressively, there will be needed, at 4% interest, to supplement the deficient amortization annuity:

When the useful life is 5 years:

$$\frac{100^2\,(1 - 0.923)}{20} = 38.5\% \text{ of the total replacement cost.}$$

When the useful life is 10 years:

$$\frac{100^2\,(1 - 0.8329)}{40} = 41.3\% \text{ of the total replacement cost.}$$

When the useful life is 20 years:

$$\frac{100^2\,(1 - 0.6716)}{80} = 42.3\% \text{ of the total replacement cost.}$$

When the useful life is 40 years:

$$\frac{100^2\,(1 - 0.4208)}{160} = 36.2\% \text{ of the total replacement cost.}$$

These figures are in substantial agreement with those resulting from the first analysis. They show that in order to make an annual allowance, estimated by the annuity amortization fund method, adequate to keep a plant, of the kind assumed, in good condition, there must be allowed to accumulate and be kept always on hand a fund at 4% interest which, for expectancies of from 5 to 40 years, is somewhere near 40% of the replacement cost of the plant.

Some such amount, depending on the expectancy, represents the accumulation of the annuities during that period of the plant's life during which no replacements were necessary. If the annual allowance for maintenance has been in the past based on the requirements of operation and repair without surplus to meet future replacements, then the current allowance for amortization or replacement should not be determined by the amortization fund annuity method, but should be otherwise determined, as shown subsequently.

When, in other words, opportunity has not been given to accumulate the 40% (approximately), for ordinary periods of useful life of

perishable properties, of the invested capital, then any amount estimated from amortization tables on the original full period of useful life, will fall short of the real replacement requirement. To illustrate this point, let it be assumed that a conduit, such as a cast-iron pipe, used for any purpose, has a length of 40 miles. Let it be also assumed that the pipe is not being further extended, that the expectancy of this pipe is 40 years, and that it was constructed progressively, 1 mile each year. It took 40 years to install the pipe, and at the end of this time, the first mile of pipe laid was ready for replacement—it had served its time. Each year thereafter, 1 mile of pipe has to be replaced, and the replacement at this rate will continue indefinitely. The annual replacement expenditure during the first 40 years is nothing, but, thereafter, it is the cost of installing 1 mile of pipe. If prices of labor and material have remained constant, and if conditions have otherwise remained as they were when the first mile of pipe was laid, then the annual replacement expenditure will be one-fortieth of the total amount invested in the pipe line.

Provision for this replacement must be made if the pipe is to continue in service. If, now, the extension of the pipe progresses beyond the 40-year period at the same rate, before assumed, of 1 mile per year, there will be no changes in the annual replacement requirement during a second period of 40 years, but at the end of this second period—at the end of 80 years—there will be 80 miles of pipe in service, and thereafter during the third 40-year period there will have to be replaced annually 2 miles of pipe, or one-fortieth of 80 miles, or twice the amount of pipe extension per annum.

It is possible, by such analysis, when a plant is of progressive growth and has attained an age exceeding the life of its perishable parts, to prescribe a rule for determining the replacement requirement; but it must be remembered that a rule thus determined can be strictly correct only for the hypothetical case of service in exact conformity with the assumed probable life, and that a rule thus determined may require some modification, as hereinafter explained.

For each group of parts having the same length of life, there is to be determined: first, the average annual capital invested, using, however, replacement cost instead of the actual investment; and second, the full number of times that the age of the plant is greater than the useful life of the particular group of parts under consideration. The

replacement requirement (for the hypothetical case, in which actual service conforms throughout with the assumed probable life) is then ascertained by multiplication.

A pipe line may again serve as an illustration: Suppose it is desired to know the replacement requirement for a pipe line 300 miles long, which has been extended 2 miles each year, the age of which, therefore, is 150 years.

The life of the pipe being taken at 40 years, the full number of times this is contained in 150 years is three. The annual replacement requirement will be three times two, or 6 miles of pipe.

The 6 miles of pipe requiring replacement were constructed 40 years ago, and the conditions under which this was done may have been materially at variance with those prevailing at the time of their replacement. Consequently, in the determination of the replacement requirement, expressed in dollars instead of in miles of pipe, the replacement cost of the system and not the original cost of capital invested should be taken into account. Expressed as a percentage of the total length of pipe in service, or of the total cost of replacing the entire pipe line, this would be 2 per cent.

By the annuity method of computation, in the selected illustration, the allowance for replacement would be 1.052% of the cost of the system, which is barely more than one-half of the actual requirement, and this allowance, as already explained, would only then be justified if amortization had covered the entire period in the life of each part of the pipe during which there was no expenditure for replacements, so that the inadequate annual allowance could be supplemented by the earnings of an accumulated amortization fund.

In a plant which is made up of a multiplicity of parts of various periods of usefulness, those which have the same expectancy should, as before stated, be grouped together. For each group, the replacement requirement can then be estimated separately, and from the several amounts thus ascertained the total requirement is determined.

The rule previously laid down for a hypothetical case is not strictly applicable under the conditions as they actually present themselves. There can be no absolute conformity between the assumed period of usefulness of any part of a plant and the time during which it actually proves useful.

The probable useful life or expectancy is merely the average life,

which is often not reached and is just as often exceeded. Thus, again referring to the pipe line, it is to be assumed that while some of it may serve beyond the average period of usefulness of such pipe, other parts thereof, from one cause or another, will require replacement early in its life. Consequently, any rule such as that previously laid down, which indicates a uniform replacement requirement in successive periods with a sudden rise in the requirement at the beginning of each new period, if the plant be one that is steadily growing, will require some modification.

The simplest modification of the foregoing rule is to assume gradual changes in the annual replacement requirement as the age of the plant increases, instead of the sudden changes, and then to call this requirement at all times inversely proportional to the useful life of any group of parts. This is sometimes referred to as the "straight-line" method. It might with equal propriety be called the direct percentage method, as the inverse ratio is usually expressed in percentage.

Under this direct percentage method, there would be allowed 2.5% per annum of the replacement cost of all parts of a plant having a 40-year life; 3.33% per annum of the replacement cost of all parts having a 30-year life; 5% per annum of the replacement cost of all parts having a 20-year life, and so on.

This method, applied to the hypothetical case of a pipe line, constructed and extended 1 mile per year, and each mile thereof having a useful life of exactly 40 years, would, at the end of the fortieth year, make the replacement requirement 2.5% per annum, or 1 mile of pipe. At the end of the sixtieth year, the requirement thus determined would be 2.5% of the 60 miles of pipe then in service, or 1.5 miles of pipe. This would be 50% in excess of the amount actually replaced, which at that time would be only 1 mile. This would also apply for any time before the pipe first laid has reached the limit of its usefulness, as at 20 years. In the assumed case there is no replacement requirement at 20 years; yet the straight percentage method indicates 2.5% of 20 miles of pipe, or 0.5 miles of pipe. It follows from this illustration that the straight-line, or direct percentage, method, applied to an estimated total cost of replacement, would give results somewhat too high.

By further analysis of this problem, the following formulas have

resulted, which are free from this objection and fulfill every ordinary requirement. In devising these formulas, the fact was taken into account that there may be some replacement requirement in the early years of a plant's life, and that this requirement gradually increases. These formulas apply strictly only to plants which have been developed gradually and are being extended at a uniform annual rate.

Using the notation already introduced, and designating with R the total cost of replacing the group of items, the probable useful life of which, when new, was n years, and with e = the average annual cost of extensions, the formulas are:

For m less than n: $r = \frac{m\ e}{2\ n}$, or $= \frac{R}{2\ n}$.

For m greater than n: $r = \frac{R}{n} - \frac{e}{2}$.

For very large values of m in relation to n (n being the years of probable usefulness), the value of this expression approaches $\frac{R}{n}$, which is the mathematical equivalent of the straight-line, or direct percentage, method.

However desirable it might otherwise appear to introduce a method of computing the replacement requirement by recourse to amortization tables, to do this equitably, in the case of a complex plant, is usually difficult, if past earnings have been inadequate to supply the proper amortization increment. In such cases the use of some formula, as above noted, for probable replacement requirement is to be recommended.

This method is strictly equitable from the standpoints of both the owner and the ratepayer. That this must be so will be seen on reflection.

The annuity or ordinary method of retirement may be regarded as an installment method. Under the replacement method an exactly equivalent lump sum, "the amount of the annuity," takes the place of the installments. If the installments are forthcoming as they are due, then the annuity method is adequate. If they are not paid, then recourse must be had to the lump sum or replacement method as above described.

It is perfectly reasonable, moreover, to assume, unless there is evidence to the contrary, that the method of estimating amortization

requirements, which prevails in any case, has been introduced deliberately. The owner of the public service property may be perfectly willing to waive the annuity payments if he knows that what they will amount to, that is, the actual annual replacement, will be covered by the gross earnings when the time comes for discarding parts of his plant. In other words, he may be willing to accept the amount of an annuity in lieu of the annuity itself; and the rate-payer may desire such an arrangement, because, in the early days of the plant's life, he may not be able to pay a sufficient amount for the service to cover the amortization annuity. It must be remembered, however, that such an arrangement burdens the future rate-payer to some extent for the benefit of the rate-payer in the early days of a plant's life. This is the same idea as the one which prompts some engineers to add early losses to the valuation as a part of that intangible value which is usually called "going concern."

It follows directly from the foregoing that there may be cases in which, even though it be found proper to allow the full actual average annual replacement, the appraisal for rate-fixing purposes should still be the entire investment without any reduction for depreciation. This will be the case whenever it can be shown that past earnings were inadequate to provide an amortization fund.

The Expectancy.

Whether the plan of making the annual replacement allowance conform to the annual actual replacement requirement, as determined by formula, be followed, or whether either of the other two methods be adopted (the direct percentage method or the annuity method), due regard should be had, in fixing the expectancy, to the circumstances under which the plant is being operated and has been operated in the past.

Such disasters as the fire and earthquake of 1906, which suddenly put out of service large portions of the public service plants of San Francisco, which would otherwise have remained useful, may properly be taken into account, as noted hereafter, in estimating the probable useful life of any part of a plant.

It must not be expected, however, that the replacement increment, by whatever method determined, will in any year exactly meet the actual replacement requirement of that year. When some unusually

costly part of the plant goes out of use and must be replaced, a single item of the replacement expense may greatly exceed the annual replacement allowance, while, on the other hand, whole series of years are to be expected in which the actual expenditure for replacement will fall below the allowance for replacement.

In the long run, if all assumptions have been properly made, there should be neither gain nor loss resulting from the allowance for replacement.

Before leaving this subject, it may be well to illustrate the fact that when the age of a growing plant is many times greater than the useful life of a class of parts, the error made in applying the direct percentage method of computing replacement requirement will be small, and may ordinarily be disregarded.

In a plant which is 63 years old, for example, and has been extended at a uniform rate, those parts which have a useful life of 5 years should, according to the correct formula, be 19.2% per annum, while, on the assumption that all the parts having a 5-year life have been replaced, or have been put in new at a uniform rate during the preceding 5 years, the replacement requirement would be figured at 20 per cent.

Absolute accuracy cannot be hoped for, whatever the method of calculation, because the premises assumed as the basis for formulas are never exactly realized. Generally, however, under consideration of all circumstances, a reasonable approximation, either by the direct percentage method or by some formula similar to those previously laid down for a special case, can be made of the actual average annual replacement requirements, whenever the amortization annuity method of retirement does not prevail.

While the process of determining the annual requirement for replacement appears to be simple, it is, as previously intimated, made somewhat difficult and uncertain of application owing to the incomplete information available, from which to estimate the useful life of a plant or of the many parts which make up the whole. Many circumstances are to be taken into account in determining useful life, for this depends not only on deterioration by natural processes of decay, or wearing away by use, but also on inadequacy resulting from growing demand upon the plant; also on inadequacy or obsolescence resulting from changes in processes of manufacture, or from the use

of new and better types of machines and appliances, and the like; and also destruction by unforeseen agencies, such as fires and earthquakes, landslides, floods, and the like. In these matters, past experience is the best guide, and, as already stated, should be given weight in some measure in assigning probable life to the parts of a plant.

In the case of gas-works, for example, the life of generators is shortened by the advance made in the art of gas manufacture. Within the last few decades, because of the high price of coal, the moderate price of oil, the local abundance of oil, and the introduction of new processes, the art of gas manufacture in California has been revolutionized. Old processes, are, for the time being, classed as obsolete, and generators and other parts of gas-works have gone out of use, in some cases, almost before their installation was completed.

Amortization and Annuity Tables.

The following tables have been prepared to illustrate certain principles, and no attempt has been made to give the figures therein presented that degree of accuracy which is usually looked for in amortization tables.

Table 7 is derived from the values noted in Tables 2, 4, and 6. It is the result of a multiplication of 100 times the figures in the column, "Remaining Value," with the figures in the next to the last column of each of these three tables.

TABLE 1.—Amortization and Annuities.

Interest at 4 per cent. Annuities applied at the end of each year.

At the end of year.	Annual Amortization Increment for Each Dollar Invested = $0.1846.			Annuity which will amount to $1 in the remaining life.	* Amount of an annuity of $0.20 in remaining life.
	Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.		
	$0.000	$1.000	$1.000	$0.1846	$1.083
1...........	0.185	0.815	0.785	0.2355	0.849
2...........	0.377	0.623	0.577	0.3204	0.624
3...........	0.576	0.424	0.376	0.4901	0.408
4...........	0.784	0.214	0.184	1.000	0.200
5...........	1.000	0.000	0.000	......	.....

* The annuity here noted is $1 divided by the expectancy.

The information contained in the tables is also presented in the curves in Figs. 1 and 2. Attention is directed to the fact, appearing in Table 7 and in Fig. 2, that the amortization increment required

to retire the remaining value in the remaining life increases from year to year.

Appraisals Without Deduction for Depreciation.

In determining the part of the investment on which the investor in public service properties should be allowed a reasonable income, all attendant circumstances must be duly considered. It may be stated, however, that, apart from the determination of the rate of interest which should result from the investment, it will be strictly equitable and fair to consider the public service corporation as the agent of the State or municipality, as the case may be, and to determine in what situation the State or municipality would have found itself had there been no intermediate owner or public service corporation.

TABLE 2.—Amortization and Annuities.

At the end of year.	Annual Amortization Increment for Each Dollar Invested = $0.833. Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.	Annuity which will amount to $1 in the remaining life.	* Amount of an annuity of $0.10 in remaining life.
	$0.000	$1.000	$1.000	$0.08329	$1.201
1	0.083	0.917	0.881	0.09449	1.058
2	0.170	0.830	0.766	0.10853	0.921
3	0.260	0.740	0.658	0.12661	0.790
4	0.354	0.646	0.552	0.15079	0.663
5	0.451	0.549	0.451	0.18463	0.542
6	0.552	0.448	0.354	0.23550	0.425
7	0.658	0.342	0.260	0.32036	0.312
8	0.767	0.233	0.170	0.49020	0.204
9	0.881	0.119	0.083	1.000	0.100
10	1.000	0.000	0.000	....	.....

* The annuity here noted is $1 divided by the expectancy.

Let it be assumed that the owner of a public service plant has made his investment under good expert advice, and that the plant is in every respect the same as, or equal to, what the people could have constructed for themselves. Let it be further assumed that the plant is free from debt, and that it and all its parts have a probable useful life of *n* years. The owner will then be entitled:

First.—To a reasonable interest on his investment;

Second.—To operating expenses;

Third.—To maintenance and repair expenditures;

Fourth.—To an annuity which, in *n* years, at the ordinary rate of interest, will amount to his investment.

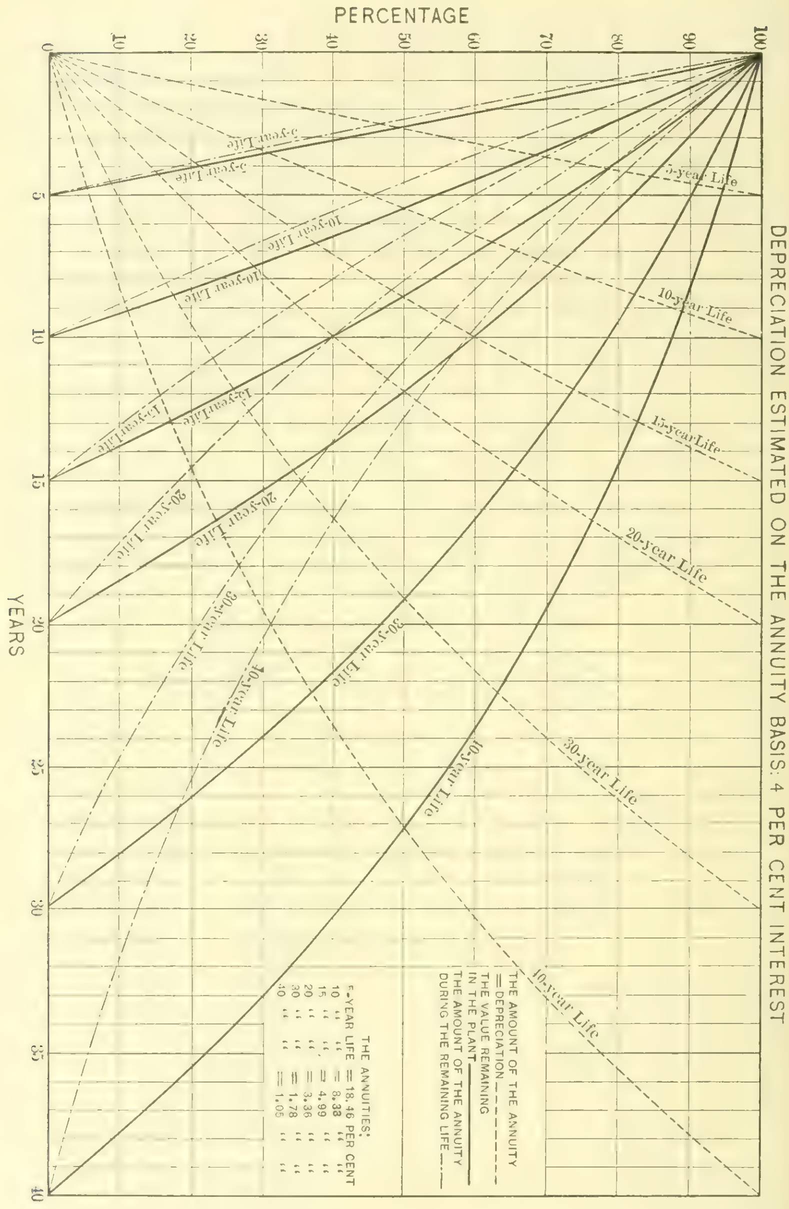

DEPRECIATION ESTIMATED ON THE ANNUITY BASIS: 4 PER CENT INTEREST
PERCENTAGE
YEARS
THE AMOUNT OF THE ANNUITY = DEPRECIATION
THE VALUE REMAINING IN THE PLANT
THE AMOUNT OF THE ANNUITY DURING THE REMAINING LIFE
THE ANNUITIES:
5-YEAR LIFE = 18.46 PER CENT
10 " " = 8.33 "
15 " " = 4.99 "
20 " " = 3.36 "
30 " " = 1.78 "
40 " " = 1.05 "
5-year Life
10-year Life
15-year Life
20-year Life
30-year Life
40-year Life

FIG. 1.

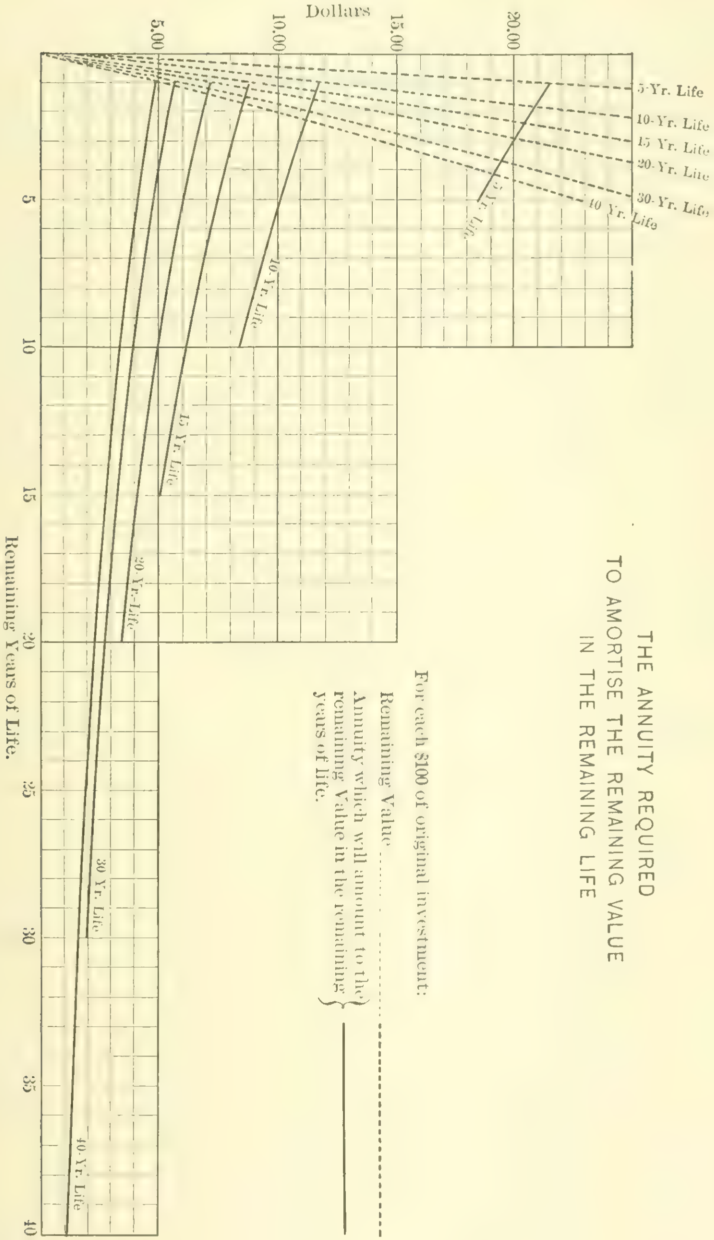

THE ANNUITY REQUIRED
TO AMORTISE THE REMAINING VALUE
IN THE REMAINING LIFE
For each $100 of original investment:
Remaining Value
Annuity which will amount to the remaining Value in the remaining years of life.
Dollars
5.00
10.00
15.00
20.00
5-Yr. Life
10-Yr. Life
15 Yr. Life
20-Yr. Life
30-Yr. Life
40 Yr. Life
10-Yr. Life
15 Yr. Life
20-Yr. Life
30 Yr. Life
40-Yr. Life
5
10
15
20
25
30
35
40
Remaining Years of Life.

Fig. 2.

TABLE 3.—Amortization and Annuities. 15-Year Expectancy.

At the end of year.	Annual Amortization Increment for Each Dollar Invested = $0.0499.			Annuity which will amount to $1 in the remaining life.	* Amount of an annuity of $0.066 ⅔ in remaining life.
	Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.		
	$0.000	$1.000	$1.000	$0.04994	$1.335
1	0.050	0.950	0.913	0.05467	1.219
2	0.102	0.898	0.830	0.06014	1.008
3	0.156	0.844	0.750	0.06655	1.002
4	0.212	0.788	0.673	0.07415	0.899
5	0.270	0.730	0.600	0.08329	0.800
6	0.331	0.670	0.529	0.09449	0.706
7	0.394	0.606	0.460	0.10853	0.614
8	0.460	0.540	0.394	0.12661	0.527
9	0.529	0.471	0.331	0.15079	0.442
10	0.600	0.400	0.270	0.18463	0.361
11	0.673	0.327	0.212	0.23550	0.283
12	0.750	0.250	0.156	0.32036	0.208
13	0.830	0.170	0.102	0.49020	0.136
14	0.913	0.087	0.050	1.000	0.067
15	1.000	0.000	0.000	......	......

* The annuity here noted is $1 divided by the expectancy.

TABLE 4.—Amortization and Annuities. 20-Year Expectancy.

At the end of year.	Annual Amortization Increment for Each Dollar Invested = $0.0336.			Annuity which will amount to $1 in the remaining life.	* Amount of an annuity of $0.05 in remaining life.
	Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.		
	$0.000	$1.000	$1.000	$0.03358	$1.489
1	0.034	0.966	0.929	0.03614	1.384
2	0.069	0.931	0.861	0.03899	1.282
3	0.105	0.895	0.795	0.04220	1.185
4	0.143	0.857	0.733	0.04582	1.091
5	0.182	0.818	0.672	0.04994	1.001
6	0.223	0.777	0.614	0.05467	0.915
7	0.265	0.735	0.558	0.06014	0.831
8	0.309	0.690	0.505	0.06655	0.751
9	0.355	0.645	0.453	0.07415	0.674
10	0.403	0.597	0.403	0.08329	0.600
11	0.453	0.547	0.355	0.09449	0.529
12	0.505	0.495	0.309	0.10853	0.461
13	0.558	0.442	0.265	0.12661	0.395
14	0.614	0.386	0.222	0.15079	0.332
15	0.672	0.328	0.182	0.18463	0.271
16	0.733	0.267	0.143	0.23550	0.212
17	0.796	0.205	0.105	0.32036	0.156
18	0.861	0.139	0.069	0.49020	0.102
19	0.929	0.071	0.034	1.000	0.050
20	1.000	0.000	0.000	....	.....

* The annuity here noted is $1 divided by the expectancy.

TABLE 5.—AMORTIZATION AND ANNUITIES. 30-YEAR EXPECTANCY.

At the end of year.	ANNUAL AMORTIZATION INCREMENT FOR EACH DOLLAR INVESTED = $0.01783			Annuity which will amount to $1 in the remaining life.	*Amount of an annuity of $0.033 $\frac{1}{3}$ in remaining life.
	Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.		
	$0.000	$1.000	$1.000	$0.01783	$1.869
1	0.018	0.982	0.944	0.01888	1.765
2	0.056	0.964	0.890	0.02001	1.665
3	0.056	0.944	0.084	0.02124	1.569
4	0.076	0.024	0.790	0.02257	1.477
5	0.097	0.903	0.743	0.02401	1.388
6	0.118	0.882	0.697	0.02559	1.303
7	0.141	0.859	0.653	0.02731	1.221
8	0.164	0.836	0.611	0.02920	1.142
9	0.189	0.811	0.570	0.03134	1.066
10	0.214	0.786	0.531	0.03358	0.993
11	0.240	0.760	0.493	0.03614	0.923
12	0.269	0.731	0.456	0.03899	0.855
13	0.296	0.704	0.423	0.04220	0.790
14	0.326	0.674	0.389	0.04582	0.727
15	0.357	0.643	0.357	0.04994	0.667
16	0.389	0.611	0.326	0.05467	0.610
17	0.423	0.577	0.296	0.06014	0.554
18	0.456	0.544	0.269	0.06655	0.501
19	0.493	0.506	0.240	0.07415	0.449
20	0.531	0.469	0.214	0.08329	0.400
21	0.570	0.430	0.189	0.09449	0.353
22	0.611	0.389	0.164	0.10853	0.353
23	0.653	0.347	0.141	0.12661	0.263
24	0.697	0.303	0.118	0.15079	0.221
25	0.743	0.257	0.097	0.18463	0.181
26	0.790	0.210	0.076	0.23550	0.142
27	0.840	0.160	0.056	0.32036	0.104
28	0.890	0.110	0.036	0.49020	0.068
29	0.944	0.056	0.018	1.000	0.033
30	1.000	0.000	0.000	....	....

*The annuity here noted is $1 divided by the expectancy.

If it be now supposed that the owner actually received these amounts, estimated on a proper basis, and that he allows the annuity to accumulate so that amortization will be an accomplished fact at the end of n years, then, as he has command of the amortization fund, he will have a decreasing amount of capital actually tied up in the plant. This decreasing capital or remaining value of the plant is the complement of the growing amortization fund. This fund is supposed to be held inviolable for the replacement of the plant at the end of its life. The owner reaps no benefit from it whatever, beyond holding it as the means for replacing a worn-out plant.

The value of the plant in its varied stages of depreciation, plus the amortization fund, should at all times be equal to the capital invested in it. The owner, if he gets an annuity, as here assumed, is entitled at all times to the interest, not on a plant valued at first cost or investment less depreciation, but on the entire first cost. Had

he determined, instead of building the plant, to keep his funds invested in safe securities at ordinary interest rates, he would, at the end of n years, have been in possession of his entire capital plus interest on the full amount thereof for the entire time. If, under the assumed facts, he were not allowed interest on the full amount invested in the public service plant, an injustice would be done.

This is true even when replacement takes the place of amortization. The owner in this case is entitled to interest on the entire capital invested in the plant, and, at the end of the plant's usefulness, he is also entitled to a return of the capital itself. Suppose that a city constructs

TABLE 6.—AMORTIZATION AND ANNUITIES. 40-YEAR EXPECTANCY.

At the end of year.	ANNUAL AMORTIZATION INCREMENT FOR EACH DOLLAR INVESTED = $0.01052.			Annuity which will amount to $1 in the remaining life.	*Amount of an annuity of $0.025 in the remaining life.
	Amount in amortization fund.	Value remaining in the physical properties.	Amount of the annuity in the remaining life.		
	$0.000	$1.000	$1.000	$0.01052	$2.376
1	0.011	0.989	0.951	0.01106	2.260
2	0.021	0.978	0.905	0.01163	2.149
3	0.033	0.967	0.860	0.01224	2.042
4	0.045	0.955	0.817	0.01289	1.940
5	0.057	0.943	0.775	0.01358	1.841
6	0.070	0.930	0.735	0.01435	1.746
7	0.083	0.917	0.697	0.01510	1.655
8	0.097	0.903	0.660	0.01593	1.567
9	0.112	0.888	0.624	0.01686	1.483
10	0.126	0.874	0.591	0.01783	1.402
11	0.142	0.858	0.557	0.01888	1.324
12	0.158	0.842	0.526	0.02001	1.249
13	0.175	0.825	0.495	0.02124	1.177
14	0.193	0.807	0.466	0.02257	1.108
15	0.211	0.789	0.438	0.02401	1.041
16	0.230	0.770	0.411	0.02559	0.977
17	0.249	0.751	0.385	0.02931	0.915
18	0.270	0.730	0.360	0.02920	0.856
19	0.291	0.709	0.336	0.03134	0.799
20	0.312	0.687	0.313	0.03358	0.744
21	0.336	0.664	0.291	0.03614	0.692
22	0.360	0.640	0.270	0.03899	0.641
23	0.385	0.615	0.249	0.04220	0.582
24	0.411	0.589	0.230	0.04582	0.546
25	0.438	0.562	0.211	0.04994	0.501
26	0.466	0.534	0.193	0.05467	0.457
27	0.495	0.505	0.175	0.06014	0.416
28	0.526	0.474	0.158	0.06755	0.376
29	0.557	0.443	0.142	0.07415	0.337
30	0.590	0.410	0.126	0.08329	0.300
31	0.624	0.376	0.112	0.09549	0.265
32	0.660	0.340	0.097	0.10853	0.230
33	0.697	0.303	0.083	0.12661	0.197
34	0.735	0.265	0.070	0.15079	0.166
35	0.775	0.225	0.057	0.18463	0.135
36	0.817	0.183	0.045	0.23550	0.106
37	0.860	0.140	0.033	0.32036	0.078
38	0.905	0.095	0.021	0.49020	0.051
39	0.051	0.049	0.011	1.000	0.025
40	1.000	0.000	0.000	....	......

* The annuity here noted is $1 divided by the expectancy.

a plant, paying cash for it and collects rates which will just yield a fair rate of interest on the investment. At the end of n years the plant is replaced with a new one of the same capacity. As the city has not included in its rates theretofore charged an increment for amortization, it now finds itself in possession of a new plant and a total investment twice as great as the cost of the first plant. Applying the same principle to the second plant, rates should be doubled. This, of course, would be an absurdity. In the first instance they should have been fixed so that the remaining value of the plant, plus an actual or imaginary amortization fund, based on full expectancy (which may have been used in the meantime for other purposes), remains constant.

TABLE 7.—ANNUITIES WHICH WILL AMOUNT TO THE REMAINING VALUE OF PERISHABLE PROPERTY IN ITS REMAINING LIFE.

For each $1 of Original Investment; 4% Interest.

At end of year.	10-YEAR EXPECTANCY.		20-YEAR EXPECTANCY.		40-YEAR EXPECTANCY.	
	Remaining life.	Annuity.	Remaining life.	Annuity.	Remaining life.	Annuity.
	10	$8.33	20	$3.36	40	$1.05
1	9	8.66	19	3.49	39	1.09
2	8	9.01	18	3.63	38	1.14
3	7	9.37	17	3.78	37	1.18
4	6	9.75	16	3.93	36	1.23
5	5	10.13	15	4.08	35	1.28
6	4	10.54	14	4.25	34	1.34
7	3	10.96	13	4.42	33	1.39
8	2	11.40	12	4.60	32	1.44
9	1	11.85	11	4.78	31	1.50
10	..	.....	10	4.97	30	1.56
11	..	.....	9	5.17	29	1.62
12	..	.....	8	5.38	28	1.68
13	..	.....	7	5.19	27	1.75
14	..	.....	6	5.82	26	1.82
15	..	.....	5	6.05	25	1.89
16	..	.....	4	6.29	24	1.97
17	..	.....	3	6.54	23	2.05
18	..	.....	2	6.79	22	2.12
19	..	.....	1	7.08	21	2.22
20	..	.....	..	....	20	2.39
21	..	.....	..	....	19	2.40
22	..	.....	..	....	18	2.49
23	..	.....	..	....	17	2.59
24	..	.....	..	....	16	2.70
25	..	.....	..	....	15	2.81
26	..	.....	..	....	14	2.92
27	..	.....	..	....	13	3.03
28	..	.....	..	....	12	3.16
29	..	.....	..	....	11	3.28
30	..	.....	..	....	10	3.41
31	..	.....	..	....	9	3.55
32	..	.....	..	....	8	3.69
33	..	.....	..	....	7	3.84
34	..	.....	..	....	6	3.99
35	..	.....	..	....	5	4.15
36	..	.....	..	....	4	4.32
37	..	.....	..	....	3	4.49
38	..	.....	..	....	2	4.67
39	..	.....	..	....	1	4.86
40	..	.....	..	....		

The same principle applied to a plant made up of a number of parts with various periods of expectancy will show that in making appraisals for rate-fixing purposes, no reduction for depreciation should be made from capital actually and reasonably invested, provided, of course, that the amortization annuity is computed on the basis of full expectancy for each part.

In other words: Though eminently proper to deduct depreciation when determining the value of a plant for an owner or a purchaser, it is fundamentally wrong to make such deduction when the plant is being appraised for rate regulation, unless, as will be hereinafter explained, the amortization be computed thereafter on the basis of the remaining life of the plant or of its parts.

This can best be made clear by an illustration: Let it be supposed that the passenger rates and the freight tariff on a steamboat line are subject to regulation, and that some one going into the steamboat business builds a steamer for the service. Let it be assumed, too, that in connection with this business he requires no capital investment other than the cost of the steamer, that terminal facilities, office space, and whatever else he needs are obtainable by rental. For the purpose of this illustration, let it be further assumed that the volume of business is such that there is no doubt about the income, so that the element of hazard is eliminated.

If, now, the steamboat has a life of 20 years, it will gradually depreciate in value and will go out of service at the end of a 20-year period. Ignoring its possible scrap value, which is immaterial for the purpose of this illustration, the following questions are to be considered.

At the end of 10 years, with interest at 4% per annum, and earnings just sufficient to yield interest plus an amortization, figured for a 20-year life at $0.03358 on each dollar of the investment:

1.—What will be the value of the steamboat to the owner at the end of 10 years?

2.—What will be the amount that a purchaser can afford to pay for the steamboat at the end of 10 years?

3.—What should the earnings be during the time the steamboat is in possession of the original owner?

4.—What should the earnings be during the time the steamboat is in the possession of a purchaser after 10 years of service?

The first and second questions have already been answered. The owner, by one line of reasoning, finds the remaining value in the steamboat to be 59.7%; the purchaser, by a different line of reasoning, finds the same value.

The third question, too, has already been answered. The original owner is entitled to a net return during the entire period of his ownership of 4% on his investment, which is at all times 100 per cent. No reduction is to be made for depreciation, because the fund which results from the accumulation of the amortization annuity, together with its interest, is available for no other purpose than the replacement of the steamboat at the end of its period of usefulness. It is dead capital, and remains dead until the property is disposed of or until required to replace the worn-out steamboat. The original owner, therefore, is entitled to a return of 4 + 3.358 = 7.358% per annum on his investment.

In considering the fourth question, it may at first appear as though the purchaser, having invested only 59.7% could claim a return on this investment alone—that he should be allowed, in addition to the amortization as above determined, net earnings of $2.388 (4% on $59.70) per annum on what he paid for each $100 of the original cost of the steamboat; that the valuation for rate-fixing purposes, in other words, should be the original investment less depreciation. Under the adoption of this view, it will be seen that, if the steamboat were sold repeatedly, there would be a constantly decreasing appraisal for rate-fixing purposes.

In the last year of its service the valuation entitled to consideration in fixing earnings would be only 7 per cent. This view is unfair to the owner of the property, who should be assumed to be planning a continuation of the steamboat business. When he takes possession of the steamer, its value to him, as already set forth, is 59.7%, but, as owner, he at once finds that, of his capital ordinarily available for other purposes, an amount equal to 40.3% of the cost of a new steamboat is tied up in his steamboat business. It has become dead capital, for all purposes except replacement, as long as he remains in the steamboat business. This 40.3% at interest at 4% is necessary to supplement the annuity regularly going into the amortization fund, together with which at the end of the 20-year period it will just replace the steamer. Whether or not the 40.3% is actually set apart is

immaterial; the fact remains that ownership of the depreciating steamer renders this amount of capital unavailable or dead for any purpose other than replacement, and the owner, no matter when he comes into possession, is entitled, therefore, to interest on this 40.3% just as fully as on the 59.7% which he paid for the steamer.

The demonstration of this fact may be made as follows: The purchaser of the steamboat, who buys the boat when it has a remaining period of usefulness of 10 years, invests, as has been explained, $59.70 for each $100 of the original cost of the steamboat. He is unquestionably entitled to interest on this sum, together with amortization, which at the assumed interest rate of 4% will be:

Interest at 4% on $59.70	$2.39
Amortization at 8.33% for the remaining 10 years, during which his investment is paid back to the purchaser	4.97
Total	$7.36

This is exactly the same as though, instead of the value of the steamboat, the capital originally invested had been taken into account, in which case the original owner or purchaser would be allowed:

Interest at 4% on the investment of $100	$4.00
Amortization annuity to retire $100 of the investment within the life of the steamboat, that is, within 20 years	3.36
Total	$7.36

Although it may be superfluous, one more illustration of this principle will be given: Let it be supposed that the owner borrows money from a bank at 4% per annum to build a steamboat, and that he earns 4% plus the amortization increment of 3.358 per cent.

Of the $7.358 to his credit at the end of each year's business for every $100 of capital invested, he pays the bank $3.358 on account of principal and so much of the remaining $4.00 as may be necessary to meet the interest then due. This will be all of the $4.00 the first year, and a decreasing amount thereafter until the end of the 20-year period, when his steamboat is retired. He then finds that he has already paid back to the bank on account of the borrowed capital twenty annuity increments of $3.358, amounting to $67.16, and that there is, therefore, still due to the bank $33.84. He also finds that the various

amounts remaining in his hands from year to year, \$0.134 at the end of the second year, \$0.269 at the end of the third year, \$0.336 at the end of the fourth year, and so on, together with interest thereon at 4%, when computed for the 20-year period will amount to the \$33.84, the balance due at the bank. The owner finds he has earned nothing. He has made no investment and has received no return, which is as it should be in this hypothetical case. The rates, however, throughout the entire 20 years were fixed on the principle that 4% per annum should always be allowed on 100% of the capital invested, together with the amortization annuity, but without any deduction for depreciation. They could not have been fixed lower without entailing loss to the owner.

The value of a revenue producing property when the earnings thereof include an amortization annuity has already been discussed. It remains to consider the case of a property which, in addition to the accepted reasonable rate of interest (net), is earning a replacement increment determined by some formula, as above explained, instead of the annuity computed from amortization tables.

In this event, each part of a plant as it wears out is replaced out of current earnings. The owner does not maintain an amortization fund, neither is any of his capital rendered dead or unavailable. To him the value of the property is at all times 100%; so, too, in the case of a purchaser. Knowing that the replacement is covered fully in the earnings, he is willing to pay 100% for the plant, regardless of its depreciation.

Take again the case of the steamboat with a life of 20 years. On the assumption that the replacement cost of the steamboat will be returned to him when the steamboat is worn out, a purchaser will pay for it at any time in its life 100 per cent. Of course, in the case of a single steamboat, it might be regarded as unreasonable to assume that in one or more remaining years of its usefulness it will earn enough in excess of reasonable interest on capital invested to pay for a new boat; but if, instead of one steamboat, there were twenty in use, and the annual replacement increment were one-twentieth of the invested capital, or one steamboat each year, then, without hesitation, the purchaser would value the property at 100 per cent.

When, therefore, the actual average annual replacement increment can be earned in excess of a reasonable interest on the invested capital,

then the appraisal for an owner, for a purchaser, and for rate-fixing purposes, would be uniformly and always 100% of the capital invested. The term, "value," in this case, means the same to the original owner, to the purchaser, and to the ratepayer.

For rate-fixing purposes the steamboat, or the business which the steamboat represents, is to be valued throughout the entire period of the steamboat's usefulness at 100%, and the earnings, when amortization is included, should be $4 + 3.358 = 7.358\%$ on this valuation.

Another case has already been considered. Suppose that, preceding the time of an appraisal for rate-fixing purposes, earnings have been inadequate to supply any amortization increment, and that it be determined thereafter to allow the actual annual replacement requirement to be earned. What, in this case, should be the appraisal?

The original investment being 100%, there having been no amortization annuity in the past, there can be no transfer of the property at less than 100% without loss; but if, by reason of inadequate returns, the market value could not be maintained at 100%, and a sale has been made at less than this sum, the new owner will be compensated and protected if, on his investment, which is not original cost, he earns reasonable interest and an adequate amount for replacements. This must be so, because, in the future, actual replacement requirements being covered by the earnings, the worn-out parts will be replaced without cost to the owner. This replacement neither increases nor decreases his investment; but, if the property is extended and new parts are added, such additions represent newly invested capital to the full amount of their cost, and in such a case his investment, expressed as a percentage of the total cost, will gradually increase.

At all times, however, without causing loss to the new owner, that part of the plant which he bought at a depreciated value could be valued at his purchase price, while all extensions subsequent to the purchase should, for rate-fixing purposes, be appraised at 100 per cent. Such a course, however, would deprive the new owner of the opportunity for profit, of which he probably thought to avail himself when he bought a plant of depreciated value, and would place the rate-payer in the position of having made a profit at the expense of the original owner. This fact, however, explains why the market value of stocks and bonds is cited so frequently as an indication of value.

It may be held that a determination of value for rate-fixing pur-

poses, on the principles herein set forth, is not a determination of value at all. This may be true, but it then becomes a matter of defining "value," and a distinction should be made between value and the appraisal of the investment on which rates may be properly based.

The term, "value," has been very generally used in matters involving the fixing of rates in the past. Perhaps when the facts herein set forth are better understood, more attention will be paid to the capital reasonably and properly invested.

The illustration with a steamboat which, though subject to constant depreciation in value, is rendering the same adequate service throughout its entire period of usefulness, was selected because thereby the fundamental principle involved is made plain. This principle is much less apparent when a plant made up of many parts of various ages and of various periods of usefulness is under consideration. For example, a plant more than 40 years old, of gradual growth, all parts of which have a life of 40 years, would have a selling value of 63.80% if the proper provision for amortization, based on full expectancy, has been made; but, in such case, it should earn reasonable interest on 100% of its cost.

A plant more than 20 years old, made up of many elements or parts, all having a useful life of 20 years, but constructed one-twentieth each year, should be worth 58.95% to a purchaser, but, with provision for amortization, as above, should earn a reasonable interest on 100% of its cost.

A plant more than 5 years old, all parts of which have a life of 5 years, constructed one-fifth each year, should be worth 61.58% of cost to a purchaser, but when the allowance for amortization is based on full expectancy, a reasonable interest should be earned in addition thereto on 100% of the investment.

It follows from the foregoing, not only that for rate-fixing the appraisal may properly be of the capital invested, but that, in determining this capital, the aggregate replacement cost, within periods not greater than the expectancy of the several perishable parts of a public service plant, may have to be taken into account.

The amount which should be returned to the owner as a replacement allowance is the capital actually invested in the part of the plant replaced from time to time. It is not the original cost, but the cost at the last renewal, which is to be returned to him, and which he is ex-

pected to re-invest with such addition thereto or subtraction therefrom as changed conditions may compel.

The account, as far as a discarded appliance is concerned, is closed, and the new appliance which takes its place, in fact represents new investment; and in its appraisal no note whatever is to be taken of the conditions under which its predecessor was constructed, or installed.

The appraisal of capital invested, therefore, should deal with conditions as they have prevailed during a longer or shorter period antedating the time of the appraisal. When a complex plant is under consideration, prices used in estimating cost should be average prices and not those prevailing at any particular time.

Under a system of permitting the owner of public service properties to earn from year to year the actual average replacement requirements, the necessity for a close distinction between repair and replacement disappears. This is of some advantage, as it is at best difficult to discriminate between small items of replacement and large repair items.

By the foregoing reasoning the conclusion seems inevitable that there may be cases in which large public service properties, such as sewer systems, harbors, railroads, and the like, the ownership of which is not limited in time by franchise, may be regarded as more or less complex plants, having practically perpetual life. The appraisal for rate-fixing purposes is then at the full amount of capital reasonably and properly invested, and there will be no deduction therefrom for depreciation. There will be no amortization if constructed on a cash basis, and all repair and replacement requirements will then appear in the expense of operation and maintenance, but with due regard to all the elements that should be taken into account.

Real estate is usually considered as requiring no allowance for depreciation, because, as a rule, real estate does not depreciate in value. However, cases are conceivable where there is depreciation, where, possibly by reason of the advance in the arts and abandonment of certain properties, the encumbered ground on which useless improvements are located may have less value than its original cost.

In such cases, if they could be foreseen, there might well be some allowance for depreciation. Ordinarily, however, there is a gradual increase in the value of real estate. This increase, strictly speaking, should be regarded as earnings, a point to which reference will be made

later. As a rule, the present value of real estate, in lieu of its first cost plus such improvements as grading, bulkheading, reclaiming against submersion, street and sewer work, and the like, may be entered on the appraisal. As the present value can generally be readily ascertained, this is usually adopted as a sufficiently close approximation of capital invested in real estate.

Intangible Values.

Ordinarily, there is neither occasion for nor propriety in adding, to an appraisal for rate-fixing purposes of a public service property, anything for intangible values, such as franchise, going concern, and the like. When an addition to the appraisal for these is made, it is most likely for the purpose of giving a name to an addition which is necessarily more or less arbitrary.

This statement, of course, does not apply when the State or a municipal authority has been paid for a franchise.* The cost of the franchise, in such a case, is a part of the legitimate investment of capital, and must be included in the appraisal. The same is true of water rights. Where adverse rights have to be quitted, or where, as under a new law in California, the State makes a charge for water rights, their cost is a legitimate expenditure, and should not be classed among the intangible values in the sense in which the term is here used.

Neither does the foregoing statement relating to intangible values apply when the appraisal is made of a property having a definite earning capacity. The sum of all intangible values is then determined by capitalization of net earnings and by deducting from such capitalization the valuation of the physical properties.

When rates are being fixed, it is quite proper to allow earnings in excess of earnings on ordinary safe investment. Such allowance may be made either direct, as an addition to the allowed rate of interest, or in the roundabout way of an addition to the appraisal.

It is possible, of course, in the case of large earnings in the past, that a portion thereof should be considered as capital returned to the owner. In such a case the fact may be of some importance that an appraisal at 100% of the investment would already include some of the intangible value.

* In San Francisco, for example, franchises for street car lines are sold to the highest bidder.

When the annual amortization increment has not been fully covered by the earnings, the deficiency is a loss. This can be made good to the owner only by increasing the earnings, which, as previously stated, is sometimes done by computing the interest to be earned, not on the invested capital alone, but on the investment plus the aggregate deficiency in the earnings of past years. Such deficiency of earnings, however, can hardly be regarded as an element of value.

Intangible values of whatsoever nature result from high earnings. In the case of public service corporations, they are arbitrarily created by agreeing to, and permitting, rates which produce a revenue in excess of the ordinary return on safe investments. They do not exist unless the rates are higher than those which would produce net earnings equalling an ordinary interest return on the properly invested capital.

It is eminently proper to treat expenditures such as the interest on capital during construction as an item of cost; yet the propriety of doing this is sometimes questioned. An inadequate interest return during the development stage is another matter. Expenditures may be incurred which can be classed as development expense, such as advertisements and the salaries of business solicitors, but these are ordinarily and with perfect propriety classed as general expense, or are otherwise included in the operating expense and enter into consideration when net earnings are estimated. In other words, they should be repaid from year to year as they are incurred, and should not be considered as a part of the capital on which the owner is entitled to a return.

In some cases, it may be possible to segregate such expenditures and to determine, too, whether they, together with the aggregate loss of interest during the unproductive period in the history of a plant or of parts of a plant, have already been made good by high rates in the past. If this is found to be the case, the element of hazard is to a large extent eliminated.

The public service corporations, naturally, would prefer to have the losses during the lean years, and such expenditures as the advertising of the business, classed as investment of capital. The apparent investment is thereby increased and the apparent aggregate profits of the business figured from the beginning of the operations are thereby made to appear larger than they would otherwise.

The fact that interest during construction is properly considered

a part of cost is, as a matter of course, as true of all work of extension and replacement as it is of original construction.

Where, as in California, the water companies and the gas companies operate under constitutional privileges, without special franchise, the hazard of the business should be covered in the earnings, and these earnings should amortize, in the course of time, a reasonable allowance for inadequate earnings, or other unavoidable losses of past years. This, of course, can be done by making an arbitrary addition to an appraisal, but then, as already stated, the hazard of the business is thrown in large measure on the rate-payer, and the rate of return must be relatively low. It is quite as effective to keep the appraisal low and make the rate of return relatively high.

There seems to be no question that the part of value usually designated as "going concern" is intended to apply to the advantage which an established business has over a corresponding prospective business, foreseen as the result of investment, but not yet established.

As long as the business is unprofitable, and as long as the rates charged do not yield a net return on the invested capital which exceeds the return obtainable from savings banks or from other investments of a character regarded as safe in the ordinary acceptance of this term, the business has no "going concern" value. This value, like franchise value, can result only from a capitalization of the excess of net earnings over the return on ordinary safe investments. It is generally a purely fictitious value, without basis other than that which results from high net earnings, but may be, and often is, regarded and defined as that portion of the intangible value for which some sort of a demonstration can be offered, as, for example, the equity of making good early losses and the deficient earnings of the past, or some estimated cost of establishing the business at the time of the appraisal, including loss of interest during an assumed time which would be required for reconstruction. It is held, with some reason, that in equity it is proper to assume that, if the community which is served by a public service property had undertaken construction and management itself, it would have subjected itself to the same losses, or at any rate to the same chances of loss, as the owner of the property, who is in some measure at least to be regarded as agent and who, as such agent, should neither be made to suffer unavoidable losses nor yet be allowed to make unreasonable profits.

The special franchise, when one exists, defines the limits within which an owner must operate. If it does not permit rates which will make the net earnings adequate, then the losses must fall without recourse on the owner; if, on the other hand, the net earnings are greater than the returns on safe investments, then, with due regard for the time during which the rates are protected by the franchise, these earnings are the basis from which, with a fair degree of precision, the aggregate amount of intangible values may be determined. These values collectively must be the difference between the capitalization of the total net earnings (properly determined) and the capital which remains, at any particular time, as an investment in the property.

The early losses and deficient earnings, when they are added to the valuation, are regarded by the appraiser as a part of the investment which had to be made to get the business going—to establish it—or at any rate to carry it along until it was on a paying basis. If this procedure should be generally accepted, it would result in giving to "going concern" the greatest value in those cases where, at the outset of the undertaking, conditions were the most unfavorable. This is an absurdity, because the valuation should be a valuation under present-day conditions, and the actual advantage which an established business has over another that would result from a duplication of the plant may be, and generally is, entirely independent of the conditions which prevailed when the established business was in its infancy.

It may be, of course, and sometimes has been held, that, if unsuccessful work and early losses are not to be added to the cost of a property, interest during construction likewise should not be treated as cost; but, in one case, there is no limit to the possible amount of unproductive expenditure, while, in the other, a definite assumption applicable in practically all cases can be made. It is not unfair to assume, for example, that in case of water- or gas-works of mature age and gradual development, some period of time, most naturally for small investments one year, will cover the average time before they commence to be remunerative. Where large and complex works are under consideration, the cost for one-half of the period of construction may be a fair allowance. The amounts thus determined are incident to every construction, whether new or whether in the nature of a hypothetical replacement, and, therefore, with perfect propriety, may

be added to cost. It is not so with the expenditures of uncertain and extremely variable amount which may be made for unsuccessful work. There may be none in one case, while in another they may be very large, as, for example, in the case of the failure of an expensive structure like a dam.

While the early losses and the expenditures for unsuccessful work are not a measure of going concern value, they are nevertheless of that class of expenditures which, in whole or in part, as already stated, should come back to the owner of the property sooner or later. To add them in the exact amount shown by the cost records in any particular case is not an invariably fair procedure. The owner who builds with care and under the best expert advice and has no such losses is entitled to a reward for his good judgment and for the care with which he has executed the works. The "going concern" value of such works is certainly as great as the going concern value of other works of a similar character and extent which, by reason, perhaps, of less care in design and execution involved a large expenditure for unsuccessful work and for the development of the business.

The combined experience on all works of a similar character, however, should, in the long run, establish the addition which should in fairness be made to the earnings to amortize an assumed fair allowance for this class of expenditures within a reasonable and not too short time. This addition may be relatively large for one type of works and small for another. It seems fair to assume that it should be relatively small when the total values are high.

Occasionally, a definite basis for at least a part of the value as an established business can be found. For example, there are cases in which the cost of making a connection with a water or gas main is a charge in whole or in part against the consumer. In such cases the cost of making the connection is no part of the capital invested by the owner of the water- or gas-works, and should not be included in an appraisal of the physical properties; but, to the extent of the cost of renewing the connections with a new system of mains, the established company has a distinct and easily recognized advantage over any new company. While not to be taken into account at all in making appraisals for rate-fixing purposes, it may, when intangible values under special franchises are to be determined, be regarded as a part of the aggregate intangible value obtained by capitalizing the

excess of the earnings over the ordinary return on safe investments not involving management.

It appears from the foregoing that, no matter how accurately the aggregate of the intangible values may be determined, it is frequently impossible to find any other than an arbitrary basis for separating them into such subdivisions as "going concern," "development of business," "franchise," "unification of system," and the like. Fortunately, such separation is rarely necessary, and, when attempted, is usually only for the purpose of giving a reason why an arbitrary allowance of earnings above those on ordinary safe investments is just and proper.

When the losses during lean years, or deficient earnings, or unproductive expenditures, such as water tunnels or wells which produce no water, structures that fail during erection, damage by fire, flood, earthquake, or explosions during erection, are added to the value as "going concern," this is unnecessary and forced. These, as has been stated, are losses, and, therefore, are to be considered and treated as the reverse of earnings. They cannot in all cases with propriety be added to the valuation of the physical properties, though it may be eminently proper, on account of such originally unforeseen circumstances, to estimate the cost of reproduction liberally.

In some form they should be taken into consideration in fixing rates. It is rarely practical to determine such losses with accuracy, and yet it is well known that very few public service plants commence operation without some untoward experience or without being compelled to do business for a time at a loss. Frequently, the expenditures for unproductive work are large, and yet this unproductive work should ordinarily be assumed to have been done under competent advice. It is assumed, in other words, that it could not be foreseen that what turned out to be unproductive work would have no value.

The easy way out of the trouble of providing compensation for such expenditures is the one frequently recommended, to add them to the valuation, giving them a name and treating them as a part of the intangible value; but, while this may appear reasonable in ordinary cases, where the expenditure for useless work and the losses in lean years have been small, other cases have occurred and can be foreseen, as already explained, in which the problem will not be as easy of solution. It is never logical.

Where there has been loss due to some unforeseen condition, due perhaps in part to error of judgment and to lack of proper foresight by the owner, it is eminently proper to let a part of this loss fall on the owner. When he embarks upon the enterprise he must be supposed to do so with the fixed purpose of reaping a profit:

1st.—In the high rates which the people practically guarantee to the owner;

2d.—In the advance in real estate and other values which make up the business.

If, now, such anticipated increase in value is allowed to the owner and the rates are fixed with a view to covering the ordinary hazards of installation and operation, and to provide proper compensation for management, then the owner on his part must stand, in part at least, the unforeseen losses, such as the destruction by flood of a partly finished dam, in the assurance that in the long run these losses will be made good, as far as they ought to be made good, by adequate compensation for the service which he renders.

It follows that all intangible values (as they may come into consideration apart from appraisals for rate-fixing purposes) should result from the inclusion of some more or less arbitrary allowance in the established rates such that earnings will exceed in some predetermined measure the earnings which would just yield the ordinary interest rate on safe investments when applied to the reproduction cost of the plant, or better yet, when applied to the actual capital reasonably and properly invested. When, for any purpose, consideration is given to intangible values thus determined, it will matter but little what name is used to designate them. It becomes comparatively easy, too, in such a case, to establish a proper relation between the tangible and intangible values, such that both owner and ratepayer may receive equitable treatment.

If it is proper to add anything for early losses, unproductive investments, and cost of developing business to an appraisal, then it is equally proper, in fairness to the rate-payer, to exclude from the appraisal all accessions of value, all appreciations which result from advance in the value of real estate and like causes, and it will also be fair and proper to keep the net earnings at and not above the ordinary return on safe investments.

When the cost of unproductive work, as just referred to, is added to the capitalization, it is with the idea that this addition shall be treated for all time as a part of the investment, and not as a loss, and that the rate-payer must bear the additional burden for all time.

When the cost of useless elements or early losses in the business are treated as losses, they should in a fair measure be made good in the course of time out of adequate earnings, and this should be done irrespective of whether every item of early loss or of every unprofitable investment can be remembered or not.

The most logical course to be pursued, and the one which is always open to the appraiser, is to use the best available means for determining the amount of capital which is properly invested, then determine what the earnings should be to yield an ordinary return on the investment thus ascertained, and then to increase those earnings by an arbitrary amount, which may vary within wide limits, not only to compensate for past losses and for the hazard during construction and operation, but also as a compensation for management.

In doing this, however, every endeavor should be made to determine correctly the cost of operation and maintenance. Maintenance is here used in its broadest sense, and must include amortization. Care must be taken, also, not to confound amortization with depreciation, because, as has been explained, an amortization annuity, figured at compound interest, is not available to retire invested capital until at the end of the life of a plant, and the existence of an amortization fund is not in itself a reason for decreasing the capital allowance on which interest is to be earned.

Fundamental Principles.

1.—The valuation of a public service property and its earnings must bear such relation to each other that there will be returned to the owner, within the life of the property, the capital which he has properly invested in it, and in addition thereto, interest at a reasonable rate, upon such amount of capital as from time to time actually and properly remains in the property as an investment.

2.—Amortization by the annuity method (the amortization or depreciation annuity being based on the full expectancy) is amortization at the end and only at the end of the period embraced in the expectancy. The invested capital remains uniform throughout the entire period.

3.—In the case of amortization by the annuity method, the value

of a plant as it would be determined for a purchaser is the cost of replacement (or original investment) less the amount of the amortization or depreciation annuity at the time of purchase.

4.—Amortization by the straight line, or direct percentage, method is amortization in annual installments. The invested capital is reduced from year to year.

5.—In the case of amortization by the straight line, or direct percentage, method, value and the appraisal for rate-fixing purposes are determined in the same way.

6.—When the annual earnings are just adequate to meet operating expenses, interest, and the annual replacement, the amount set apart for replacements will not reduce the invested capital.

7.—A public service property which consists of a single perishable item may, at any time of its life, be appraised at 100% of the capital properly invested, provided that amortization, estimated by the annuity method for the full expectancy, has been allowed from the beginning.

8.—A public service property which consists of a single perishable item may, at any time of its life, be appraised at the investment less depreciation (determined by any method), and amortization may then be computed for the remaining value thus determined, but must be based on the remaining years of the property's usefulness.

9.—A public service property made up of numerous items, all of which have the same expectancy, may be appraised at 100% of the investment, and amortization should then be allowed from the beginning, and the full expectancy should be used in computing it.

10.—A public service property made up of numerous items, all of which have the same expectancy, may have each item valued separately, as under Paragraph 8, with deduction for depreciation, and with amortization allowed for the remaining life of each item.

11.—A public service property, of gradual growth and mature age, made up of numerous items of the same expectancy, when the assumption is justified that the annual rate of extension has been uniform, may be appraised at investment less an average depreciation, and amortization is then to be allowed for the equivalent remaining life of an equivalent single item.

12.—When a public service property is made up of many items of various expectancies, the property may be appraised at 100% of the investment, and, amortization being allowed from the beginning, this

is to be estimated on the basis of the full expectancy of each group of items of equal expectancy.

13.—When a public service property is made up of many items of various expectancies, each item may be dealt with separately as under Paragraph 8, or groups of items may be dealt with as under Paragraph 11.

14.—When the special case is presented in which there has been no amortization earned in the past, it will be proper to substitute the annual actual replacement requirement in lieu of amortization. The appraisal should then be at 100% of the capital properly invested.

15.—When the amortization annuity is based on the full expectancy and remains at this amount throughout the life of a plant, then no part of the amortization can be applied to retire the investment until the close of the period of useful life, when the amortization fund will be equal to the investment. In case it be thus applied, a new amortization rate for the remaining life and the remaining value must be introduced into the calculation. Table 7 gives such rates for a few expectancies.

16.—When the appraisal for rate-fixing purposes is investment less depreciation, and earnings have not included amortization in the past, then, under amortization computed by the annuity method for the full original expectancy, the owner will be operating at a loss.

17.—Proper investments for franchises, for water rights, and the like, are always to be included in the appraisal.

18.—Intangible values should be disregarded, in making appraisals for rate-fixing purposes, excepting only when the rate of net return is deliberately fixed at or too near the rate earned by ordinary safe investments, in which case an arbitrary addition to the appraisal, under whatever name, should be made. The interest on this item of the appraisal will be the reward of the owner for management and for any hazard which the business may involve.

19.—The net earnings of a public service property should in some measure exceed the return from ordinary safe investments.

20.—The appraisal of real estate should be at its present value.

21.—When the increase of the value of a public service property, due to increase in the value of real estate or like causes, is determinable in advance, such increase may be taken into account as a part of the current earnings.

22.—When, in the past, there has been increase of value, due to increase in value of real estate or like causes, this is to be offset against losses during lean years. The increase in value represents reinvested earnings.

It is to be noted, as set forth in Paragraphs 8, 10, 11, and 13, that a valuation for rate-fixing purposes at less than the original investment of capital may be perfectly proper. It represents the remaining investment; but, when the original investment less amortization or depreciation is introduced into the calculation, amortization requires special consideration, because it must be entered at a new and increasing amount from year to year. Reference may be had to Table 7 which makes this point clear.

Notwithstanding the great disadvantage attendant upon valuation at original investment less depreciation, such valuations are being made and are therefore being herein fully considered.

In explanation of the statement that the earnings of a public service property should be somewhat greater than those of ordinary safe investments, reference may again be had to the case of an owner of a public service property who invests only borrowed money. If he receives only such interest on the investment as he must pay to the bank, he will have rendered a service without compensation, except such as he may be allowed in salaries, under operating expenses. In such case, it would be a proper business arrangement to compensate him for the risk of loss which he assumes, and for his management, and to make this compensation in some measure proportional to the net earnings. If the owner in the cited case is a stock company, this compensation will be the only element giving value to the capital stock of the company.

The Appraisal at Cost of Reproduction.

The objection may be made that, in the practical application of these principles, the capital properly invested cannot always be determined with sufficient accuracy.

It is reasonable to expect that, under good and intelligent direction, and competent expert advice, every dollar invested in a public service property will have been properly expended. Under less able management, there may be a waste of capital, and the works, when completed, will then have cost more than they should. The book

accounts, therefore, cannot be accepted as conclusive evidence, even when it can be shown that the cost account has been properly kept. What is wanted is a method or plan of valuation which can be applied under all circumstances in perfect fairness to both the owner of a property and to the ratepayer. There appears to be none better than that of estimating the capital, properly invested, by an appraisal of the public service property at cost of reproduction, item for item, using, however, as a basis for appraisal, not the prices of labor and material which prevail on any particular day, but the prices which represent averages for some considerable time in the past.

Under this method of appraisal, which is recommended as fair in estimating capital reasonably and properly invested, only properties in use are to be included in the appraisal, and under it the owner who has built with intelligence and economy finds himself liberally treated, while the owner who has built wastefully and has incurred useless expenditures is made to bear the penalty of his wastefulness.

Increase in value not represented by a direct investment of capital, as in the case of an appreciation of the value of real estate, may properly be regarded in the light of earnings when regulating rates. Such appreciation of value may also result from other causes, as in the case of an advance in the prices of material and labor, which would make the reproduction of a plant cost more than has actually been invested in it. On the other hand, there may be a decrease in value due to reduced prices of material or labor and the like. These changes are generally gradual and, when treated as income, or as expense, and distributed over a series of years, usually affect the general result but slightly.

In many cases, not only the increase in the value of real estate is small, but also the proportion of its value to the entire value of a property. In such cases, if there is uncertainty about first cost plus the cost of improvements, such as grading, filling, bulkheading, street and sewer work, the error made in ignoring the effect of a change in the value of the real estate will be small. A doubling of value in 40 years, for example, is equivalent to a rate of increase of 0.52% per year of the value at the end of the 40-year period. A doubling of value in 20 years is equivalent to a rate of increase of 1.68% per year of the value at the end of the 20-year period.

These percentages, if the real estate represents 10% of the total

appraisal, would appear in the earnings as 0.17% and 0.05% per annum of the total appraisal; but, when appreciation of value is treated as earnings, then that portion of the earnings available for distribution is less than it would otherwise be, and the appreciation becomes in fact a reinvestment of earnings, and should be properly taken into account in making an appraisal of invested capital.

Thus, in the case of a property which has appreciated in value 100% in 40 years, if this appreciation has been the same in amount each year, and if it could have been determined in advance, there would have been entered into the calculation earnings by appreciation gradually decreasing as the property increased in value from 1.05 to 0.52% per annum. The rate of interest to be earned and distributed would have been decreased by these amounts. An appraisal at any time would then have taken the properties into account at their appreciated value.

In practical application of such a principle, difficulty arises in determining what allowance to make for the possible annual appreciation. No general rule can be laid down for this determination. It will probably be found that in most cases, in view of the small rate of appreciation, offset as it may be by losses and by depreciation not otherwise taken into account, this appreciation should go to the owner of the property as a more or less indeterminate part of the profit to which he is entitled.

Unless, therefore, there is good reason for taking into account the appreciation or the depreciation in the value of real estate as an addition to or a deduction from earnings, this element may be neglected. This is also true of all that portion of the plant which has increased in value by reason of an advance in the cost of labor and materials, in case the appraisal is based on the estimated cost of reproduction, as explained, because, in that event, the appraisal, being based on prices as they have prevailed during considerable time periods, will ordinarily show only moderate and gradual changes of value.

Disadvantage of Annual Rate Regulation.

In California the law requires that the water rates, to be charged by public service corporations which supply water to the inhabitants of cities and towns, shall be fixed annually by the proper authority. This requirement does not make for efficient service. It would be

better, both for the owner of the public service property and for the ratepayer, to have rates regulated with less frequency. A 5-year interval would probably be about right. The certainty that an acceptable rate will prevail for at least a 5-year period would be an inducement to the public service corporations to render satisfactory service. Extensions would be made more willingly, and the needs of the ratepayer would be more likely to receive proper consideration than under the prevailing system of annual rate regulation, which involves in constant uncertainty business relating to the immediate future. The owner of the plant, knowing that each year his profit may be cut off by an inadequate rate limit, hesitates to make any investment beyond what may be imperatively demanded, with the result that the service becomes unsatisfactory or inadequate.

The Appraisal of the Investment.

It has been made clear in the foregoing that a valuation of the purely physical elements of a public service property (depreciation deducted), coupled with an allowance of amortization computed for the full expectancy, as is frequently done, would be inadequate as a basis for rate regulation. This fact is generally recognized by engineers who are called on to make appraisals for such purposes, and no doubt the amounts added as intangible values are sometimes intended to make good such deficiency, at least in part, even when the appraiser does not know why his appraisal is inadequate.

The necessity in such cases for the addition of something to the value of the purely physical elements of a public service property undoubtedly exists; but on the method of determining the amount of the addition, there has not heretofore been agreement. This is due to the imperfect analysis which has been made of such investments, from the business man's standpoint, and to the ruling of the Courts, which hold that owners of public service properties are entitled to a fair return on the "value" of such properties.

If it be found that the ruling of the Courts is not subject to modification, or, in other words, that appraisals must be "value," as "value" would be determined by a purchaser, that is to say, for the tangible elements in most cases, cost or cost of replacement less depreciation, or something practically equivalent thereto, then the appraisers making the valuation, who adhere to the method of computing amortization

on the full expectancy, will be constrained to find intangible values in one form or another which will swell the appraisal to where they would like to see it for rate-regulation purposes, that is, about, or somewhat above, the amount of capital reasonably and properly invested.

Of course, a special franchise granting excessive returns is out of consideration in this statement. In such a case, the intangible values are real values determinable by a capitalization of earnings and a subtraction of the value of the tangible parts of the property.

It follows, too, that ordinarily it makes very little difference whether the intangible value is called "going concern," or "franchise," nor how it is arrived at, nor in what proportion it is apportioned to these two classes of value, nor whether a part thereof be otherwise designated, as for example, "adaptation and solidification of roadbed," as was done in a recent valuation of the railroads in Minnesota.

After all has been said, it will be found true that the adoption of the method of valuation for rate-regulation purposes at the investment without deducting depreciation (as herein advocated) will be always applicable, and, if properly applied, will protect the interests of both owner and ratepayer. It has a distinct advantage over other methods, which are involved in more or less obscurity and cannot be standardized. It will be resisted by certain corporations, the values of whose properties, based on earning power, have been greatly inflated, because thereby the facts showing the relation between net earnings and the capital properly invested in any enterprise are made apparent. It will be welcomed by the rate-payer and by all boards or commissions charged with regulating rates, and if generally adopted, will lead ultimately to a careful analysis of earnings by all owners of public service properties, in order that actual net earnings may be determined correctly. The relation of net earnings to the properly invested capital will always remain the most important factor to be weighed, when rates are to be regulated.

The excess of these earnings over the earnings which would represent a return on ordinary safe investments are the reward which the owner receives, as has been stated, for his management of the property and for assuming risks. By reason of the fact that the replacement or amortization requirement is necessarily more or less conjectural, the prospective net earnings cannot ordinarily be estimated closely. This is an additional reason why the rate of return should be made

liberal. Any addition to the rate of return is then a purely arbitrary addition, and this addition capitalized, if there is certainty that it will be earned, is the real basis for the intangible values as they would be taken into consideration by a purchaser.

Of course, the proceeding can be reversed, and an arbitrary addition can be made to the appraisal, to which the rate of return is then applied in estimating what the earnings should be. It makes no difference, in the ultimate result, at which end the addition is made, and the appraiser in this matter may follow his own inclination.

Recent Court Decisions.

The United States Supreme Court, in Knoxville *vs.* Knoxville Water Company,* says:

"The first fact essential to the conclusion of the court below is the valuation of the property devoted to the public uses, upon which the company is entitled to earn a return. That valuation ($608,000) must now be considered. It was made up by adding to the appraisement, in minute detail of all the tangible property, the sum of $10,000 for 'organization, promotion, etc.,' and $60,000 for 'going concern.' The latter sum we understand to be an expression of the added value of the plant as a whole over the sum of the values of its component parts, which is attached to it because it is in active and successful operation and earning a return. We express no opinion as to the propriety of including these two items in the valuation of the plant, for the purpose for which it is valued in this case, but leave that question to be considered when it necessarily arises. We assume, without deciding, that these items were properly added in this case. The value of the tangible property found by the master is, of course, $608,000 lessened by $70,000, the value attributed to the intangible property, making $538,000. This valuation was determined by the master by ascertaining what it would cost, at the date of the ordinance, to reproduce the existing plant as a new plant. The cost of reproduction is one way of ascertaining the present value of a plant like that of a water company, but that test would lead to obviously incorrect results, if the cost of reproduction is not diminished by the depreciation which has come from age and use.

†"The cost of reproduction is not always a fair measure of the present value of a plant which has been in use for many years. The items composing the plant depreciate in value from year to year in a varying degree. Some pieces of property, like real estate, for instance, depreciate not at all, and sometimes, on the other hand, appreciate.

* United States Reports, Vol. 212, p. 9.

† *Loc. cit.*, p. 10.

But the reservoirs, the mains, the service pipes, structures upon real estate, stand-pipes, pumps, boilers, meters, tools, and appliances of every kind, begin to depreciate with more or less rapidity from the moment of their first use. It is not easy to fix at any given time the amount of depreciation of a plant whose component parts are of different ages with different expectations of life. But it is clear that some substantial allowance for depreciation ought to have been made in this case."

* * * * * * *

*"A water plant, with all its additions, begins to depreciate in value from the moment of its use. Before coming to the question of profit at all, the company is entitled to earn a sufficient sum annually to provide not only for current repairs but for making good the depreciation and replacing the parts of the property when they come to the end of their life. The company is not bound to see its property gradually waste, without making provision out of earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that at the end of any given term of years the original investment remains as it was at the beginning. It is not only the right of the company to make such a provision, but it is its duty to its bond and stockholders, and, in the case of a public service corporation, at least, its plain duty to the public. If a different course were pursued the only method of providing for replacement of property which has ceased to be useful would be the investment of new capital and the issue of new bonds or stocks. This course would lead to a constantly increasing variance between present value and bond and stock capitalization—a tendency which would inevitably lead to disaster either to the stockholders or to the public, or both. If, however, a company fails to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purpose of earning a return cannot be enhanced by a consideration of the errors of the management which have been committed in the past."

* * * * * * *

"After the company had closed its case the city undertook to determine the present value of the company's property by the plain method of ascertaining the cost of reproduction, diminished by depreciation. In its case in rebuttal, the company followed the same method, though the results differed largely, and, as we have seen, *no proper allowance for depreciation was made.*"

---

* *Loc. cit.*, p. 13.

The United States Supreme Court, in Willcox *et al.*, constituting the Public Service Commission of New York, *vs.* Consolidated Gas Company, says:*

"And we concur with the court below in holding that the value of the property is to be determined as of the time when the inquiry is made regarding the rates. If the property, which legally enters into the consideration of the question of rates, has increased in value since it was acquired, the company is entitled to the benefit of such increase. This is, at any rate, the general rule. We do not say there may not possibly be an exception to it, where the property may have increased so enormously in value as to render a rate permitting a reasonable return upon such increased value unjust to the public. How such facts should be treated is not a question now before us, as this case does not present it. We refer to the matter only for the purpose of stating that the decision herein does not prevent an inquiry into the question when, if ever, it should be necessarily presented."

In the same case, the United States Supreme Court holds that a valuation of $12 000 000 for the franchise, to be added to a valuation of $47 000 000 for physical properties, is excessive.

This value was arrived at, by the lower court, by assuming a constancy of relation between the value of franchise and the value of the tangible property. The franchise value had been fixed in 1884 by agreement of the companies which consolidated, at $7 781 000. This valuation received some sanction or endorsement by a legislative committee, which investigated the consolidation in 1885, and expressed the opinion that this valuation of franchise was not more than its fair value.

At the time of the consolidation the physical properties were valued at $30 000 000; the accepted value of the franchise at that time, therefore, was 26% of the value of the tangible properties.

By applying 26% to the increased valuation in 1906 of the tangible properties, or to $47 000 000, the lower court reached the conclusion that the franchise value had increased to more than $12 000 000, the value disapproved by the Supreme Court. The Court says:†

"But although the State ought, for these reasons, to be bound to recognize the value agreed upon in 1884 as part of the property upon which a reasonable return can be demanded, we do not think an increase in that valuation ought to be allowed upon the theory suggested by the court below. Because the amount of gas supplied has

* United States Reports, Vol. 212, p. 52.

† *Loc. cit.*, pp. 47 and 48.

increased to the extent stated, and the other and tangible property of the corporations has increased so largely in value, is not, as it seems to us, any reason for attributing a like proportional increase in the value of the franchises.

"Real estate may have increased in value very largely, as also the personal property, without any necessary increase in the value of the franchises. Its past value was founded upon the opportunity of obtaining these enormous and excessive returns upon the property of the company, without legislative interference with the price for the supply of gas, but that immunity for the future was, of course, uncertain, and the moment it ceased and the legislature reduced the earnings to a reasonable sum the great value of the franchises would be at once unfavorably affected, but how much so it is not possible for us now to see. The value would most certainly not increase.

"What has been said herein regarding the value of the franchises in this case has been necessarily founded upon its own peculiar facts, and the decision thereon can form no precedent in regard to the valuation of franchises generally, where the facts are not similar to those in the case before us. We simply accept the sum named as the value under the circumstances stated."

The Supreme Court, in these recent opinions, does not refer to the method used in estimating the depreciation or amortization increment which must have entered into the calculation of net return. If this was properly determined in the Knoxville case on the basis of the remaining useful life of the several parts of the water-works, then the opinion of the Court relating to the valuation in that case is eminently proper; but the statement of facts in connection with this point is not clear. Neither does the Court have anything to say about it. The Court no doubt assumed that the method of computation was a correct one. In other words, if error was committed at all it was not the error of the Court.

It may be assumed, therefore, that the decision was rendered just as it would have been if amortization had been correctly determined (as it may have been), and as far as ultimate result is concerned, the decision of the Court is in accord with the principles which have herein been noted; but, for the sake of standardizing and simplying the method of arriving at the desired result, the Supreme Court might with propriety, when opportunity arises, qualify the opinion expressed in the Knoxville case so that all questions of the permissibility, either to make the appraisal of value for rate-fixing purposes with depreciation deducted, or, as an alternative, to make the appraisal a fair

appraisal of the amount of invested capital, using in each case the proper method of computing the amortization annuity, will be set at rest.

Comparison of Various Methods of Computing Interest and Amortization.

To make it clear that the two methods of valuation for rate-fixing purposes lead to identical results, a pipe line of mature age may again be used for illustration, and reference may also be had to the case of the steamboat already cited. The expectancy of the pipe line is 40 years; it has been constructed progressively one-fortieth each year. There will be one-fortieth of the pipe 40 years old. This has served its time and is of no value. Another fortieth has served 39 years, and its remaining value (after deducting the amount in the amortization fund due to this fortieth) will be 4.8% of the cost of replacing it. Another fortieth, 38 years old, will have a depreciation value of 9.5%, and so on. The last fortieth, being new, will have full value. The average value, as has already been stated, will be 63.8%, or $63.80 for each $100 of the total investment. The remaining life which must be assumed for an equivalent unit of this value is 18.0 years.

The computation, on the theory of valuation approved by the U. S. Supreme Court, will now be as follows:

Depreciated value of the pipe line for each $100 of the investment	$63.80	
Amortization increment to be applied annually, which will amount to $63.80 in the remaining 18.0 years at 4 per cent		$2.50
Net earnings on $63.80 at the assumed rate of 4% per annum		2.55
Total earnings in excess of operating expenses		$5.05

The computation, on the principle of valuing the investment without deduction for depreciation, will be as follows:

The investment will be	$100.00	
The amortization increment to be applied annually, which will amount to $100 in 40 years at 4% will be		$1.05
The net earnings on $100 of the investment at 4% will be		4.00
The total earnings in excess of operating expenses, etc.		$5.05

The earnings, including amortization, estimated by the two methods are identical. They are also identical in the case of a single depreciating item, as in the case of the steamboat at 10 years, or at any other period of its life. They will always be identical, whether the plant is large or small, simple or complex.

The simple method of making appraisals should, in the end, find general acceptance, and when the fact of the absolute agreement of this method with that laid down in the Knoxville case is properly brought to the attention of the Courts, it may be expected that it will obtain their approval.

In Table 8, and by the diagram, Fig. 3, the results of computing earnings according to five different methods are presented. All figures in Table 8 apply to $100 of invested capital. The interest rate on safe investments is taken at 4% per annum. Similar tables and diagrams could have been prepared for other expectancies than 20 years, and for other rates of interest, but this single table will suffice to make clear the fundamental principles which are involved, and particularly the fact that the results by the simplest method of all, No. 1, always coincide exactly with the results by Method No. 3, the latter being in unquestioned conformity with the opinion of the U. S. Supreme Court, as recently expressed in the Knoxville case.

The first method of computing earnings, as illustrated in Table 8 for a 20-year life at 4% per annum, as has been fully explained, is based on a valuation at all times at 100% of the investment. The amortization fund is supposed to be held as a part of the property, transferable with it, and the amortization increment is not written off as depreciation. The several amounts paid into the amortization fund are not available to the owner until replacement is necessary at the end of the term of the plant's usefulness. The moment they are applied as a retirement of capital, it becomes necessary to compute amortization for the remaining value and the remaining life. When this is done annually, the result is as shown under Method No. 3.

The second method is an approximation which is not generally applicable. It is proper for a complex plant of mature age, when it can be shown that there has been no opportunity to accumulate an amortization fund; when, in other words, the allowance for amortization has not exceeded the requirement for replacement. A modification of this method results from the application of the formula for

replacement, as elsewhere noted, to be used in the case of plants of a uniform rate of growth.

The introduction of the annual replacement requirement properly determined by any method, in place of amortization, would make Method No. 2 of computing earnings generally applicable in all cases in which past amortization increments have not exceeded the replacement requirements.

TABLE 8.—METHODS OF CALCULATING ANNUAL INTEREST AND AMORTIZATION FOR AN EXPECTANCY OF TWENTY YEARS.

Method No. 1.

For each $100 of original investment. Interest 4 per cent.

At the end of year.	VALUATION=INVESTMENT WITHOUT DEDUCTION FOR DEPRECIATION. Amortization Based on Expectancy.			
	Valuation for each $100 of investment.	Interest at 4% per annum.	Annual amortization increment.	Net earnings, including amortization.
0	$100.00	$4.00	$3.36	$7.36
1	100.00	4.00	3.36	7.36
2	100.00	4.00	3.36	7.36
3	100.00	4.00	3.36	7.36
4	100.00	4.00	3.36	7.36
5	100.00	4.00	3.36	7.36
6	100.00	4.00	3.36	7.36
7	100.00	4.00	3.36	7.36
8	100.00	4.00	3.36	7.36
9	100.00	4.00	3.36	7.36
10	100.00	4.00	3.36	7.36
11	100.00	4.00	3.36	7.36
12	100.00	4.00	3.36	7.36
13	100.00	4.00	3.36	7.36
14	100.00	4.00	3.36	7.36
15	100.00	4.00	3.36	7.36
16	100.00	4.00	3.36	7.36
17	100.00	4.00	3.36	7.36
18	100.00	4.00	3.36	7.36
19	100.00	4.00	3.36	7.36
20	100.00	4.00	3.36	7.36
Averages	$100.00	$4.00	$3.36	$7.36

The third method is that which literally conforms to the recent Supreme Court decisions, already quoted. Depreciation is taken into account in making the valuation, and amortization is estimated for this valuation and the remaining life. This agrees absolutely with Method No. 1. It is based strictly on the assumption that the amortization is synonymous with depreciation, and is deducted from the investment as each annual increment is received. The annual, gradu-

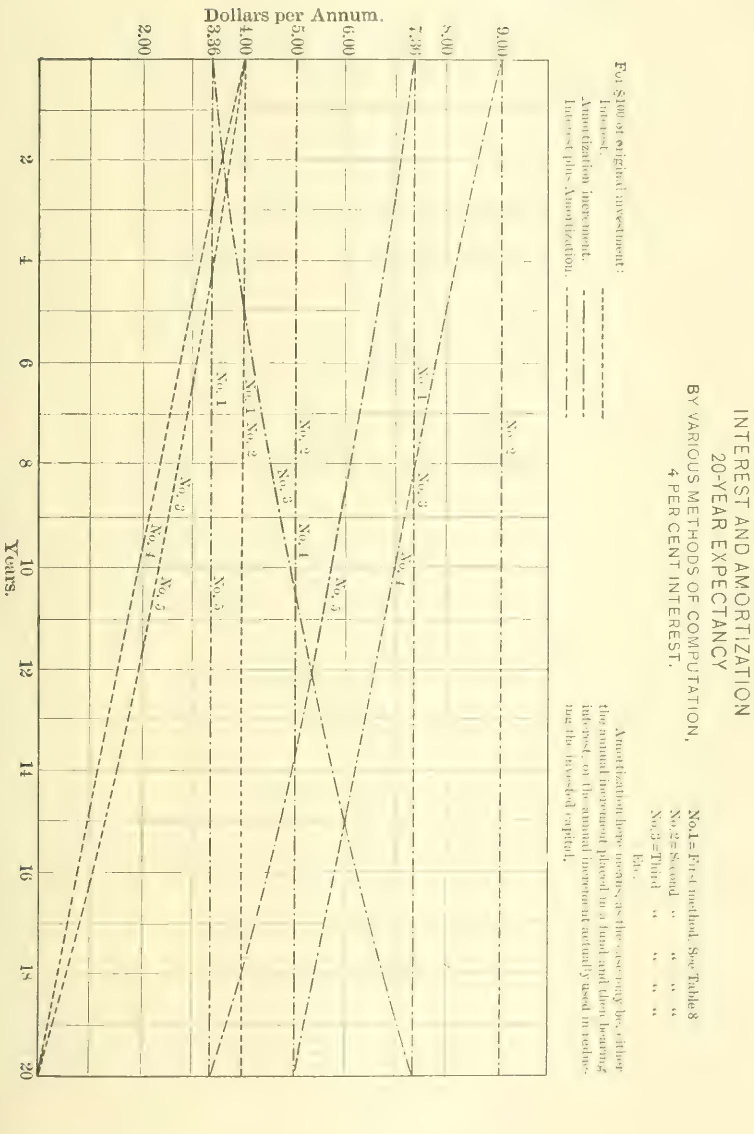

INTEREST AND AMORTIZATION
20-YEAR EXPECTANCY
BY VARIOUS METHODS OF COMPUTATION,
4 PER CENT INTEREST.
No.1 = First method. See Table 8
No.2 = Second " " " "
No.3 = Third " " " "
Etc.
Amortization here means, as the case may be, either the annual increment placed in a fund and then bearing interest, or the annual increment actually used in reducing the invested capital.
For $100 of original investment:
Interest.
Amortization increment.
Interest plus Amortization.
Dollars per Annum.
9.00
8.00
7.39
6.00
5.00
4.00
3.36
2.00
Years.
2
4
6
8
10
12
14
16
18
20
No. 1
No. 2
No. 3
No. 4
No. 5

Fig. 8.

ally increasing amortization or depreciation increment, under Method No. 3, can be ascertained by formula as follows:

Let a represent the amortization annuity for the full or original expectancy (the same as under Method No. 1).

i represent the rate of interest used in determining the annuity.

n be the number of the year for the end of which the depreciation increment is to be estimated.

A_i represent the depreciation increment for the year, n:

$$\text{Then: } A_i = \frac{100\,a}{i}\left[\left(\frac{100+i}{100}\right)^{n+1} - \left(\frac{100+i}{100}\right)^{n}\right]$$

For $i = 4$, that is, for an interest rate of 4%, this will be:

$$A_4 = 25\,a\,(1.04^{n+1} - 1.04^{n})$$

For $i = 3$, there will be:

$$A_3 = 33.33\,a\,(1.03^{n+1} - 1.03^{n})$$

For $i = 5$, there will be:

$$A_5 = 20\,a\,(1.05^{n+1} - 1.05^{n})$$

The fourth method, based on a valuation which takes depreciation into account and allows an annual amortization increment determined by the direct percentage method, has the serious defect of requiring large earnings in the early years of a plant's life and smaller earnings toward the end of its life. This defect is fatal to its general application. It may find occasional application, however, as a convenient method of approximating the required earnings in the case of complex plants of mature age, but, even then, as is shown by the line of averages in the table, the probability is that it will be in some measure unfair to the owner. It will give results in strict accord with those of Methods Nos. 1 and 3 at only a single period of the life of a plant, as for example, at 4.2 years for a plant (or an item) having a 10-year life; at 8.2 years for a plant having a 20-year life, and at 14.5 years for a plant having a 40-year life, and so on.

The fifth method is incorrect, and is decidedly unfair to the owner. It is to be condemned under all circumstances, notwithstanding the fact that it gives nearly correct results in the early years of a plant's life.

The averages at the bottom of Table 8 are the valuations and amounts which apply in the case of equal groups of items of every

possible age. The average amortization noted for Method No. 3 is the same as the amount which would be estimated by the straight percentage method. This is true for any life, not alone for the 20-year period, to which the table applies. In other words, when amortization has been properly allowed from the beginning, in the case of a complex plant as described, the earnings are to include interest on the remaining investment and amortization computed by the straight percentage method.

In the case of a plant made up of many parts of various periods of useful life, the practice is sometimes followed of estimating depreciation for each group of parts of equal life (n years) at one-nth of the remaining book value.

TABLE 8 (*Continued*).—Methods of Calculating Annual Interest and Amortization for an Expectancy of Twenty Years.

Method No. 2.

(An approximation method applicable in special cases only.)

For each $100 of original investment. Interest 4 per cent.

At the end of year.	Valuation = Investment without Deduction for Depreciation.			
	Amortization by Straight Percentage.			
	Valuation for each $100 of investment.	Interest at 4% per annum.	Annual amortization increment.*	Net earnings, including amortization.
0	$100.00	$4.00	$5.00	$9.00
1	100.00	4.00	5.00	9.00
2	100.00	4.00	5.00	9.00
3	100.00	4.00	5.00	9.00
4	100.00	4.00	5.00	9.00
5	100.00	4.00	5.00	9.00
6	100.00	4.00	5.00	9.00
7	100.00	4.00	5.00	9.00
8	100.00	4.00	5.00	9.00
9	100.00	4.00	5.00	9.00
10	100.00	4.00	5.00	9.00
11	100.00	4.00	5.00	9.00
12	100.00	4.00	5.00	9.00
13	100.00	4.00	5.00	9.00
14	100.00	4.00	5.00	9.00
15	100.00	4.00	5.00	9.00
16	100.00	4.00	5.00	9.00
17	100.00	4.00	5.00	9.00
18	100.00	4.00	5.00	9.00
19	100.00	4.00	5.00	9.00
20	100.00	4.00	5.00	9.00
Averages	$100.00	$4.00	$5.00	$9.00

* In the case of a plant of mature age, made up of numerous parts, amortization as here noted is the annual replacement requirement.

TABLE 8 (*Continued*).—METHODS OF CALCULATING ANNUAL INTEREST AND AMORTIZATION FOR AN EXPECTANCY OF TWENTY YEARS.

Method No. 3.

For each $100 of original investment. Interest 4 per cent.

At the end of year.	VALUATION=INVESTMENT LESS DEPRECIATION. Amortization Based on the Remaining Life.			
	Valuation for each $100 of investment.	Interest at 4% per annum.	Annual amortization increment.	Net earnings, including amortization.
0	$100.00	$4.00	$3.36	$7.36
1	96.64	3.86	3.49	7.36
2	93.15	3.73	3.63	7.36
3	89.52	3.58	3.76	7.36
4	85.94	3.43	3.93	7.36
5	80.81	3.27	4.09	7.36
6	77.73	3.11	4.25	7.36
7	73.48	2.94	4.42	7.36
8	69.06	2.76	4.60	7.36
9	64.46	2.58	4.78	7.36
10	59.68	2.39	4.97	7.36
11	54.71	2.19	5.17	7.36
12	49.54	1.98	5.38	7.36
13	44.16	1.78	5.59	7.36
14	38.57	1.54	5.82	7.36
15	32.76	1.31	6.05	7.36
16	26.71	1.07	6.29	7.36
17	20.42	0.82	6.54	7.36
18	13.88	0.56	6.80	7.36
19	7.08	0.28	7.08	7.36
20	0.00	0.00	7.36	7.36
Averages	$58.95	$2.36	$5.00	$7.36

Under such practice, the average book value of each $100 of original investment, if the plant has mature age and its parts are uniformly distributed to all possible ages, will be about as follows:

In a group having a 5-year life................$67.23
" " " 10 " " 65.15
" " " 20 " " 64.15
" " " 30 " " 63.83
" " " 40 " " 63.68

Interest and amortization (in this case the assumed depreciation) would be figured as follows:

5-Year Life:

Interest on $67.23 at 4 %.................... = $2.69
Amortization, 20% of $67.23.................. = 13.45

$16.14

Whereas interest plus amortization should be, at least.... 22.64

10-Year Life:

Interest on \$65.15 at 4% . . . . = \$2.61
Amortization, 10% of \$65.15 . . . . = 6.52

\$9.13

Whereas interest plus amortization should be, at least 12.33

20-Year Life:

Interest on \$64.15 at 4% . . . . = \$2.57
Amortization, 5% on \$64.15 . . . . = 3.21

\$5.78

Whereas interest plus amortization should be, at least 7.36

40-Year Life:

Interest on \$63.68 at 4% . . . . = \$2.55
Amortization, 2.5% on \$63.68 . . . . = 1.59

\$4.14

Whereas interest plus amortization should be, at least 5.05

TABLE 8 (*Continued*).—METHODS OF CALCULATING ANNUAL INTEREST AND AMORTIZATION FOR AN EXPECTANCY OF TWENTY YEARS.

Method No. 4.

For each \$100 of original investment. Interest 4 per cent.

At the end of year.	VALUATION = INVESTMENT LESS DEPRECIATION. Amortization Based on Straight Percentage.			
	Valuation for each \$100 of investment.	Interest at 4% per annum.	Annual amortization increment.	Net earnings, including amortization.
0	\$100.00	\$4.00	\$5.00	\$9.00
1	95.00	3.80	5.00	8.80
2	90.00	3.60	5.00	8.60
3	85.00	3.40	5.00	8.40
4	80.00	3.20	5.00	8.20
5	75.00	3.00	5.00	8.00
6	70.00	2.80	5.00	7.80
7	65.00	2.60	5.00	7.60
8	60.00	2.40	5.00	7.40
9	55.00	2.20	5.00	7.20
10	50.00	2.00	5.00	7.00
11	45.00	1.80	5.00	6.80
12	40.00	1.60	5.00	6.60
13	35.00	1.40	5.00	6.40
14	30.00	1.20	5.00	6.20
15	25.00	1.00	5.00	6.00
16	20.00	0.80	5.00	5.80
17	15.00	0.60	5.00	5.60
18	10.00	0.40	5.00	5.40
19	5.00	0.20	5.00	5.20
20	0.00	0.00	5.00	5.00
Averages	\$50.00	\$2.00	\$5.00	\$7.00

TABLE 8 (*Continued*).—METHODS OF CALCULATING ANNUAL INTEREST AND AMORTIZATION FOR AN EXPECTANCY OF TWENTY YEARS.

Method No. 5.

(Always erroneous.)

For each $100 of original investment. Interest 4 per cent.

At the end of year.	VALUATION = INVESTMENT LESS DEPRECIATION. Amortization Based on the Full Expectancy.			
	Valuation for each $100 of investment.	Interest at 4% per annum.	Annual amortization increment.	Net earnings, including amortization.
0	$100.00	$4.00	$3.36	$7.36
1	96.64	3.86	3.36	7.22
2	93.15	3.73	3.36	7.09
3	89.52	3.58	3.36	6.94
4	85.74	3.43	3.36	6.79
5	81.81	3.27	3.36	6.51
6	77.73	3.11	3.36	6.47
7	73.48	2.94	3.36	6.30
8	69.06	2.76	3.36	6.12
9	64.46	2.58	3.36	5.94
10	59.68	2.39	3.36	5.75
11	54.71	2.19	3.36	5.55
12	49.54	1.98	3.36	5.34
13	44.16	1.78	3.36	5.14
14	38.57	1.54	3.36	4.90
15	32.76	1.31	3.36	4.67
16	26.71	1.07	3.36	4.43
17	20.42	0.82	3.36	4.18
18	13.88	0.56	3.36	3.92
19	7.08	0.28	3.36	3.64
20	0.00	0.00	3.36	3.36
Averages	$58.99	$2.36	$3.36	$5.72

The amortization increment computed by this method is clearly inadequate.

It is now possible to prepare tables for various expectancies which will show the required earnings (not including any allowance for management), including amortization, computed by methods which have been shown to be proper.

Table 9 is based on Method No. 1 (Table 8). The property is appraised for rate-fixing purposes at 100% of the investment, and the original expectancy is made the basis of computing the annual amortization increment. In this table the interest column is not, strictly speaking, based on the true value of the property, neither is the amortization annuity noted in the following column in strict conformity with the growth of an annuity fund, but the sum of the two

columns is the correct sum of these two increments which are to be covered by the earnings. (The same rate of interest is supposed to apply throughout.)

TABLE 9.—INTEREST AND AMORTIZATION FOR ANY PLANT OF ANY AGE.

Method No. 1 (Table 8).

Generally Applicable.

For each $100 of original investment. Interest 4 per cent.

Expectancy, in years.	Appraisal.	Interest.	Amortization annuity.	Interest plus amortization.
5	$100	$4.00	$18.463	$22.46
6	100	4.00	15.079	19.08
7	100	4.00	12.661	16.66
8	100	4.00	10.853	14.85
9	100	4.00	9.449	13.45
10	100	4.00	8.329	12.33
15	100	4.00	4.994	8.99
20	100	4.00	3.358	7.36
25	100	4.00	2.401	6.40
30	100	4.00	1.783	5.78
35	100	4.00	1.358	5.36
40	100	4.00	1.052	5.05
45	100	4.00	0.826	4.83
50	100	4.00	0.655	4.66

Due to the fact that a page of the author's manuscript was omitted in sending in the paper, the description of Table 10 has to be left out of this preliminary publication.

It is worthy of note, in the case of numerous parts of the same expectancy uniformly distributed to all possible ages, as will be seen by reference to Table 10, that, when depreciation is estimated by the annuity method, and is properly deducted from the invested capital, under Method No. 3, the annual amortization or depreciation increment is the same as though determined by the straight line method.

The method of appraisal and computation of earnings illustrated in Table 11 is substantially correct for a plant of mature age when the annual replacement requirement may be substituted for the amortization. It is not likely that there will have been an excess of income during the early years of a plant's service. The early years are generally lean years, which are ordinarily expected to produce less than the desired income. Therefore, apart from exceptional cases, it may be generally assumed that a plant when it has reached mature age should be earning the replacement requirement in addition to a reasonable rate of interest on the investment.

TABLE 10.—Interest and Amortization.

Average values for plants of numerous parts uniformly distributed to all possible ages.

Method No. 3 (Table 8).

For each $100 of original investment. Interest 4 per cent.

Expectancy.	Remaining life of equivalent single item, in years.	Average remaining value.	Interest on remaining value.	Amortization annuity for remaining life.	Interest plus amortization.
5	3.0	$61.58	$2.463	$20.000	$22.46
6	3.5	60.30	2.412	16.067	19.08
7	4.0	59.38	2.375	14.286	16.66
8	4.5	58.83	2.353	12.500	14.85
9	4.9	58.45	2.338	11.111	13.45
10	5.3	58.23	2.329	10.000	12.33
15	7.6	58.18	2.327	6.667	8.99
20	9.9	58.95	2.358	5.000	7.36
25	12.0	60.03	2.401	4.000	6.40
30	14.1	61.25	2.450	3.333	5.78
35	16.0	62.53	2.501	2.857	5.36
40	17.9	63.80	2.552	2.500	5.05
45	19.7	65.10	2.604	2.222	4.83
50	21.5	66.38	2.655	2.000	4.66

TABLE 11.—Interest and Amortization.

For Plants of Mature Age in Case that the Amortization Earned in the Past has not Exceeded the Replacement Requirements.

Method No. 4 (Table 8).

For each $100 of original investment. Interest 4 per cent.

Expectancy.	Appraisal.	Interest.	Annual amortization or replacement requirement.	Interest plus amortization.
5	$100	$4.00	$20.00	$24.00
6	100	4.00	16.67	20.67
7	100	4.00	14.29	18.29
8	100	4.00	12.50	16.50
9	100	4.00	11.11	15.11
10	100	4.00	10.00	14.00
15	100	4.00	6.67	10.67
20	100	4.00	5.00	9.00
25	100	4.00	4.00	8.00
30	100	4.00	3.33	7.33
35	100	4.00	2.86	6.86
40	100	4.00	2.50	6.50
45	100	4.00	2.22	6.22
50	100	4.00	2.00	6.00

If, however, it can be shown that the investment has been cut down by excessive earnings or by a direct repayment of capital, as in the case of municipal or State aid by contribution of funds to the owner, then the interest rate should be applied only to the remaining investment.

Method No. 4, Tables 8 and 11, is practically equivalent to a computation of the replacement requirement for inclusion in the earnings. When, however, a new plant of numerous parts is in question, all the expectancies of which are n years, it would be better to grade the replacement increment from nothing at the beginning to one-nth of the investment in the nth year.

The practice has heretofore been so general of assuming that the amortization annuity, based on the original expectancy, was an adequate amortization allowance that there may be cases in which such allowance was from year to year erroneously deducted from the investment as depreciation, Method No. 5, Table 8. Let the case be considered where this has been done for a plant with a 20-year useful life. When this plant is 10 years of age the owner will have received ten annual amortization payments of \$3.36. These, under this assumption, were applied to reduce the capital invested when he received them. At the 10-year period, therefore, there is a value of \$67.40 left in the plant for each \$100 of original investment. The earnings should be interest on this amount at 4%, or \$2.70 plus the amortization for \$67.40 for the remaining 10 years, or (\$67.40 × 0.0833) = \$5.61, making \$8.31. If the plan of allowing interest on the reduced valuation plus the original amortization increment of \$3.36 had been followed, the earnings of (\$2.70 + \$3.36 =) \$6.06 would be inadequate.

Conclusion.

Thus far, no distinction has been made between expectancy and the actual life. All computations have been made as though there were absolute conformity between the actual life and the expectancy. This, however, is never strictly true, because some items of every group will go out of use before they are of mature age, while others will survive their expectancy.

The amortization annuity estimated for the actual life of a large number of items will not necessarily agree with the amortization annuity based on average probable life. That there must be disagreement will readily be seen when a single item is taken into consideration. This may be one of those doomed to fail early; or it may be one of the large number which will reach a mature age; or it may be among the smaller number which serves long after the expected age has been passed. Taking all probabilities into account

when the item is new, it will be found that the amortization rate which should apply will always conform to an actual life somewhat less than the expectancy.

It is not proposed to follow this matter further, nor to attempt a specific illustration which would necessarily have to be based on some assumption relating to mortality unsubstantiated by experience; but there may be found in this fact some justification for making liberal allowance for amortization from the beginning of a plant's service.

According to the Court opinions previously quoted, there is a distinct recognition by the United States Supreme Court of the propriety of including intangible values in the appraisal for rate-regulation purposes. The Court, however, indicates no method by which the value of a franchise is to be determined. It states distinctly that the opinion in the New York gas rate case is not to be considered a general precedent.

There is also a distinct recognition of the fundamental principle that the value of the investment should be maintained as at the beginning. This is strictly correct if it is intended to apply to the value of the properties as a business and not to the tangible properties alone. There is hardly room to doubt that this is the actual meaning intended to be conveyed, because a little further on the Court says that the tangible properties of water-works and the like begin to depreciate on the day they go into use. Such depreciation of the tangible properties, as referred to by the Court, cannot be offset or made good by any amount of repair work, because, to all intents and purposes, the depreciated items may continue for a long time to be rendering just as adequate service, and often even better service, than when first installed. To be kept at 100% of the investment, the appraisal would at all times have to be the value of the physical properties plus the amortization fund.

The difference between the value of the tangible property and the invested capital might, perhaps, according to this interpretation of the language used by the Court, be a proper measure of the intangible values; but, if thus measured, they serve merely as an excuse for bringing the valuation up to the investment, and, in that event, the amortization increment must be based on the full expectancy of the plant. In applying such a principle, account must be taken of the gradually decreasing value of the intangible elements. The steamboat in the last

year of its life would be valued at 7%, and the intangible values appurtenant to the steamboat business would aggregate 93 per cent. No one would pay more than 7% for the boat, yet, as has been demonstrated, the rates may properly be based on a valuation of the steamboat business at 100 per cent.

This, of course, is an extreme case, but it illustrates the principle. Perhaps no Court has ever been asked to allow so large a proportion of intangible value. Yet the principle remains the same whether at 5 years the intangible value is 18% of the entire appraisal, or whether at 19 years it is 93% thereof. This undesirable feature should condemn the use of intangible values to bring the appraisal up to the actual investment.

It will be much better to use the equivalent and uniformly applicable method of determining by the best available means what amount of capital is properly and reasonably invested. The attempt to draw sharply the line which separates the tangible from the intangible value should be discouraged.

If it were customary to maintain the amortization fund, perhaps by investment in outside securities, as an integral and inseparable part of the property, growing as depreciation increases and subject to transfer with the property as a part thereof, in case of a sale, then the fundamental principle, already fully explained, that the appraisal at all times should be at 100% of the investment, would be readily understood. It would then be clear that the earnings of the amortization fund would go into the property for replacement purposes, and that at all times the owner would be entitled, in addition to such earnings, to a proper rate of return on 100% of the investment, that is to say, on the value remaining in the physical property plus the amortization fund.

The Supreme Court distinctly lays down the principle that, as a general rule, increase in value should go to the owner of a property. This is a confirmation of the views previously set forth. First, that, strictly speaking, the increase should be treated as reinvested earnings; second, that, under the difficulty which will always exist of predicting from past experience what the future may bring, it will rarely be possible to estimate the future increment of earnings due to appreciation with sufficient certainty to take it into account in estimating the prospective surplus or revenue over expense, and, whenever this can-

not be done, such increase of value will, in fact, go, as the Supreme Court says it should, to the owner; but, when, as an exception to the rule, which exception is pointed out by the Court, the property has increased enormously in value, then the fairness of taking account of the increase as a part of the earnings becomes apparent.

The foregoing is based throughout on the assumption that the ordinary rate of interest on safe investments is alone taken into account, and that any addition to this rate will be made as a direct addition to the earnings computed at this ordinary rate. The addition may be expressed either in percentage of the original investment, or in percentage of the remaining investment, or true value, as ordinarily understood and as defined by the U. S. Supreme Court in the Knoxville case. The latter may be found desirable, when, as should ordinarily be the case, the amortization has been earned from the beginning, but, for this purpose alone, a close estimate of actual value is not essential.

The results presented in Table 8 are made the basis of the curves shown in Fig. 3. Particular attention is asked to the lines marked No. 1 and No. 3. The sum of the ordinates of the two No. 3 lines, representing "interest" and "amortization," is always the same, and agrees throughout with the sum of the ordinates of the horizontal "interest" and "amortization" lines for No. 1. The diagram indicates plainly the extent of the departure of the other methods of calculation from the correct ones.

Method No. 1, according to which the appraisal for rate-fixing purposes is the investment without any reduction for depreciation, has certain advantages over Methods Nos. 3 and 4, the only other strictly correct methods of calculating allowable earnings, which may be briefly stated as follows:

Method No. 1 is always applicable when it can be shown that earnings have been adequate in the past, no matter whether the property is a single item, or is composed of many items; whether the expectancy is long or short; whether the expectancy is uniform for all parts of the property or not; whether the plant is of mature age or not; whether the property has attained full growth or whether it is still growing at a uniform rate, or otherwise. It is simple of application, and does not involve determination of the present condition of the property, provided that it is maintained in proper condi-

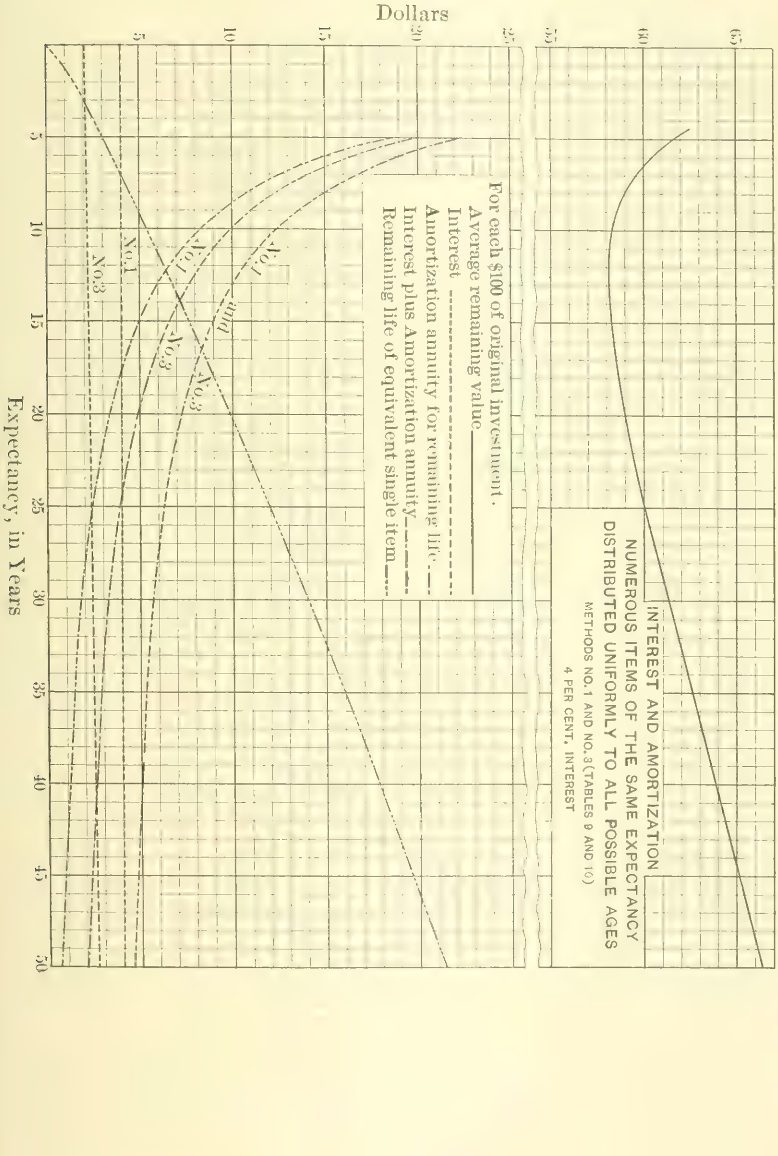

Dollars
Expectancy, in Years
For each $100 of original investment.
Average remaining value
Interest
Amortization annuity for remaining life
Interest plus Amortization annuity
Remaining life of equivalent single item
INTEREST AND AMORTIZATION
NUMEROUS ITEMS OF THE SAME EXPECTANCY
DISTRIBUTED UNIFORMLY TO ALL POSSIBLE AGES
METHODS NO.1 AND NO.3 (TABLES 9 AND 10)
4 PER CENT. INTEREST
No.1
No.3
No.1 and No.3

Fig. 4.

tion to render adequate service. It furnishes all the information necessary for intelligent action in fixing rates, because when it is known what the net earnings, above operating expenses, must be to yield the return which money should earn in ordinary safe investments, then an arbitrary addition can be made, to compensate the owner for management and risk of loss.

In contrast with these advantages, Method No. 3, under which "value" as ordinarily understood must be determined by deducting depreciation from the investment, requires a special determination of value for each item of which the property is composed, and a new determination every year for every item, or in special cases, for every group of items of the same expectancy. Each item has a new value each year and a remaining life which grows continually shorter. Amortization, therefore, must be estimated on a new basis each year. The judgment of the expert is called into play to determine the condition and probable remaining life of the several parts of the property, and after the complex calculation is made, if the same basic rate of interest is used throughout, the result should agree absolutely with the simpler Method No. 1.

When, for any reason, the rate of interest to be earned on the investment is higher than the rate of interest applied to the amortization annuity (in estimating depreciation) then, under Method No. 3, the net earnings will follow a descending scale. The rates to be charged, full compensation being assumed, will be higher in the early years of a plant's life than in its last years. This is an undesirable feature, resulting from the application of Method No. 3. It is avoided under Method No. 1. Herein is found an additional reason for the general adoption of the method of appraisal for rate-fixing purposes under which no deduction from the invested capital need be made for depreciation.

An advantage that may properly be claimed for Method No. 3 lies in this, that it discloses, more or less approximately, the part of the capital remaining in the property, and therefore, actual value of its tangible elements as such value would be estimated by a purchaser.

Method No. 4 not only has the same disadvantages as No. 3, but it is not acceptable, as has been explained, owing to the decrease of the earnings with increasing age of the plant. Its results do not, as do those of No. 3, agree from year to year with those of Method No. 1.

No. 5 is a method of approximation which is applicable whenever a plant, made up of numerous parts, has mature age, and it can be shown that in the past the earnings have been inadequate to supply an amortization fund, in excess of replacement requirement, which fund approximates 40% of the total investment in perishable properties; and when no part of the invested capital has been otherwise returned to the owner.

When the practice shall have been established of writing off nothing from the investment for depreciation, there will be a modification of the ordinary system of keeping accounts. It will then be desirable to open an "amortization and replacement account," which will be debited with the amount of the amortization actually earned, and there will be credited against it every item of replacement. The discarded items will be credited to the account of "invested capital" at their cost, and this account will be debited with the cost of the new items which replace the old.

It will be practical, too, to combine the replacement and the repair accounts whenever for any reason this may appear desirable. The depreciated value, according to the book accounts, under such a system, can at any time be found by subtracting the amount in the amortization fund from the invested capital.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROVISION FOR UPLIFT AND ICE PRESSURE IN DESIGNING MASONRY DAMS.

Discussion.*

By Messrs. William Cain, J. W. Ledoux, and L. J. Le Conte.

William Cain, M. Am. Soc. C. E. (by letter).—In the provisions for uplift presented in Cases 2 and 3,† the author suggests that the upward pressure at the heel of the dam be taken as approximately equal to the static head. The writer suggests that this is too great an allowance. The uplift for a full static head, along the heel, could only occur, even approximately, where the foundation was composed of hard spheres, like marbles. In the case of gravel or earth, the pores are closed more or less with fine material, and the uplift is much less. Mr. Cain.

By experimenting with saturated sand, on a small scale, J. C. Meem,‡ M. Am. Soc. C. E., has proved that the water pressure on a given area, through sand having 40% voids, was about 40% of that due to the static head. Such a conclusion seems to be reasonable, and, if it should be confirmed by experiments on a large scale, for various materials, it would add greatly to our present knowledge. As Mr. Meem emphasizes,§ a gauge placed in the dam or foundation may register the full static head, but this does not prove that the full pressure is exerted over the whole foundation, but only over a portion, as his experiments indicate.

Mr. Wegmann has brought out the well-known fact that many high dams on good foundations, in the design of which no uplift was considered, have stood for years; and that, to allow for a full uplift in high dams, the dimensions would have to be increased beyond reason. Doubtless some uplift exists in all dams, but it is the writer's

* Continued from March, 1912, *Proceedings*.

† *Proceedings*, Am. Soc. C. E., November, 1911, p. 1196.

‡ *Transactions*, Am. Soc. C. E., Vol. LXX, pp. 365-372.

§ *Proceedings*, Am. Soc. C. E., February, 1912, p. 179.

Mr. Cain. opinion that, at the heel, it never exceeds that due to half the static head, and is probably much less where a deep fill is placed against the up-stream face. It might then be supposed to decrease uniformly to zero at the toe, when the water which percolates there has free exit; but if it is under a head at the toe, then the uplift pressure there "will be equal to the head required to overcome the resistance to the water escaping at that point."

When saturated earth rests against the dam, on either face, it is a common error to find the weight per cubic foot of the earth in water, by subtracting from its weight in air the weight of a cubic foot of water. By this method, if the weight of earth in air is 100 lb. per cu. ft., the weight in water will be 100 — 62.5 = 37.5 lb. Assume that the earth has 40% voids; then 1 cu. ft. of earth contains 0.6 cu. ft. of solids, and the buoyant force of the water is the weight of an equal volume of water, or $0.6 \times 62.5 = 37.5$ lb.; hence the true weight of the earth in water is $100 - 37.5 = 62.5$ lb. per cu. ft., instead of 37.5 lb., as found by the erroneous method.

In computing the thrust due to the saturated earth against the dam, this weight, 62.5 lb. per cu. ft., for the earth, must be used if the full head of water is supposed to act on the dam. The full thrust on the dam will thus be the resultant of the earth thrust and the water thrust, as computed from the assumptions. It is certainly on the side of safety to proceed thus for the up-stream face, and, from our present lack of definite knowledge as to the modifying influence of the earth in diminishing the water thrust, the writer advises that this method be followed in designing.

If, however, future experiments should confirm Mr. Meem's small-scale experiments, the analysis would be as follows: Assume that an earth with 40% voids, transmits only 40% of the water pressure due to the full static head; then the water pressure on the dam from the surface of the saturated earth downward, will be only 40% of that due to the static head.

As regards the earth, a cubic foot with 40% of voids and having, therefore, only 0.6 cu. ft. of solids, will now be subjected to a buoyant force of only,

$$0.4 \times 0.6 \times 62.5 = 15 \text{ lb.};$$

hence, earth weighing 100 lb. per cu. ft, in air, will weigh $100 - 15 = 85$ lb. in water. With this weight, the earth thrust is computed for the proper coefficient of friction of earth in water. A similar treatment would apply to any saturated filling on the down-stream face.

Recurring again to uplift, engineers until recently have omitted consideration of it in the design of dams, thus being on the side of danger. To counterbalance this, however, the full hydrostatic pressure has been supposed to act on that part of the dam which is in contact with the

saturated filling (which sometimes extends to half the height of the dam), whereas there are good reasons for supposing that a much smaller pressure is exerted on this lower portion. From similar reasoning, it might be well to omit consideration of the pressure of any saturated filling on the down-stream face. It would seem that the amount of uplift should be taken in the increasing order for granite, sandstone, stratified rock with horizontal seams, earth, and gravel. In any case, cut-off walls and drains are desirable, especially in seamy rock where extensive grouting of crevices may also be required. Mr. Cain.

As the amount of uplift thus varies with different materials, and is an unknown quantity in any case, it should be left to the discretion of a competent engineer. It would be most unfortunate if a law was passed specifying a given uplift for all cases.

As to ice pressure, the writer thinks it should be allowed for in certain cases. In fact, as far as he knows, he was the first to suggest that allowance should be made for the influence of ice, floating bodies, etc.* It was also stated,† on the authority of Thomas C. Keefer, Past-President, Am. Soc. C. E., that "an ice bridge of about 90-ft. span, between two fixed abutments, expanded so from a rise of temperature, as to rise 3 ft. in the center." This afforded an opportunity to make a quantitative estimate of the ice thrust, and it was utilized at once with other data, in revising the cross-section of the proposed Quaker Bridge Dam by the Board of Engineers. As is well known, the design recommended by that Board, meritorious as it was, and in advance of any previous design, was not adopted finally.

The writer is glad to note that both ice pressure and uplift have been considered in the Kensico and Olive Bridge Dams. It remains now to go further and, by experiments on a large scale, determine, more closely than hitherto, the amount of this uplift and the allied subject, the hydrostatic pressure of ground-water.

In conclusion, the writer's thanks are due to the author for his timely paper and for the fair and comprehensive manner in which he has presented the main points at issue.

J. W. Ledoux, M. Am. Soc. C. E. (by letter).—This is a very important subject, and one on which pertinent facts and the judgment of engineers with large experience in this particular line are valuable. Unfortunately, however, there is evidence that some of those who have taken part in the discussion have not had this broad experience, as their judgment appears to be erroneous. Mr. Ledoux.

It is not by any means certain that the failure of the dam at Austin, Pa., was due to upward pressure. It is quite probable that if upward pressure were excluded entirely, the dam would have failed in

* *Engineering News*, June 23d, 1888.

† *Engineering News*, June 30th, 1888.

Mr. Ledoux. exactly the same manner. It is a question of the coefficient of friction. The dam did not go down into rock, but only rested on or near the surface. These rock layers were nearly horizontal, from 2 to 6 in. or more in thickness, and parted by unctuous clay. The coefficient of friction between two surfaces of rock separated by clay or soft, wet shale may not be more than from 0.3 to 0.5, while the dam at Austin would probably have failed if the coefficient had been 0.55.

It is a mistake to become hysterical about upward pressure, and there is a possibility that it is of minor consequence in dams in which the design and construction are carried out in a reasonable way. Some one has made experiments recently which convince him that upward pressure is exerted only in the voids in the material. In other words, if a dam rested on sand having only 40% of voids, the maximum possible upward pressure would be 40% of the bottom area of the dam. If a dam rests on rock, and the concrete or masonry is reasonably constructed with flush mortar, the chances are that the voids are far less than 40%, and if this be considered and the fact that the maximum pressure is greatest at the up-stream toe of the dam and zero at the down-stream toe, the total upward pressure under the dam could not exceed 0.2 of the hydrostatic pressure. However, if the rock foundation contains a horizontal crack a short distance below the base of the dam, the upward pressure might be considerably greater.

If a dam is built of good concrete or masonry with good Portland cement mortar, and the design is ample, there is no danger of defects occurring in the structure itself which will cause failure, such as temperature cracks or cracks due to placing new work on work which has been finished for a considerable time. These should be provided against as far as possible, but, in the writer's experience, they have never been known in themselves to cause the failure of a dam or retaining wall. If a masonry or concrete dam without reinforcement has been finished in warm weather, it is almost certain that vertical transverse cracks, from top to bottom, will occur as soon as very cold weather comes. These are large enough at times to permit considerable seepage of water. Before the winter is over, however, these cracks close up, the leakage disappears, and in the next season they can hardly be found. The filling is probably an efflorescence of magnesia or lime from the cement; therefore, these temperature cracks are not of sufficient consequence to warrant the use of expansion joints, and, besides, the quantity of reinforcement required to prevent them would be extremely large, and the results obtained would not warrant the expenditure. If a dam is built of concrete and contains a very large proportion of boulders or heavy rocks of good quality, it is possible that these cracks will not occur, but this opinion is not based on a sufficient number of cases to be absolutely reliable. In

building large dams, it is necessary to depend on all kinds of labor, and it is not possible to have the same kind of expert labor on the concrete as is constantly employed by the best sidewalk cement paving companies. If it were, it might be possible to build a dam which would not crack or check on account of changes of temperature. Mr. Ledoux.

No engineer of experience cares to build a masonry dam at all unless he can found it on a material which has sufficient bearing power. The limit in this respect might be considered shale rock, which would bear safely at least 10 tons per sq. ft. Such a rock, of course, is not capable of withstanding erosion due to falling water, therefore, means must be supplied to prevent overtopping the dam in floods. In other words, an independent spillway must be provided. Where this is impossible and it is necessary for the water in floods to pass over the center of the dam, if the material on which the dam is founded will not resist erosion, the only thing to do is to provide an apron of heavy stone laid in mortar and 10 ft. or more in thickness; the upper surface of this apron should be below the water level and be carried down stream 20 ft. or more, depending on the height of the dam.

To prevent water from passing under the dam, a cut-off trench must be sunk to reasonably impervious material. Such a trench need not be more than 6 ft. wide, and should be under the up-stream toe. Of course, it is filled with concrete or masonry and thoroughly incorporated with the main structure of the dam, but the main portion of the dam should go deep enough to have a sufficient barrier of natural material to prevent it from sliding. In most cases 10 ft. in rock will be sufficient for this, but if the dam is very high a greater depth becomes necessary. Down stream from this trench the writer believes it would be good practice to place longitudinal open drains and connect them at frequent intervals with transverse drains extending down stream, so as to eliminate as far as possible the effects of upward pressure. This can be done without any material increase in cost, and is far better than to assume an excessive upward pressure and then build the dam of sufficient section to resist it.

To provide against a possibility of trouble during construction, English engineers usually leave, in the lower part of the dam, an opening sufficiently large to carry away any possible floods. Concrete a week old will stand for a short time a large depth of water running over it without danger of destructive erosion, so that excessive precaution in this respect seems to be unwarranted, except in a case where the water flowing over the dam would erode the material from the down-stream toe. These openings are usually circular in form, and are recessed so that the masonry or concrete finally placed will dovetail in with the remainder of the work.

The writer never had much apprehension concerning ice pressure.

Mr Ledoux. If the expanse of ice is very great, it would appear that no material pressure could be exerted without crushing the ice, due to the effect acting on a long column. The main danger is with the coping, where water may freeze in horizontal cracks and lift the stones. Of course, this can be obviated by putting heavy steel bolts through the coping, embedding them in the masonry to a depth of 4 to 5 ft. Where the ends of the dam are close to vertical rock cliffs, the danger of destruction at these points, due to ice pressure, becomes very much greater, because the ice has no chance to slide up along the ground, and the distance is so short that the column weakness is not material. This consideration, however, is theoretical rather than practical, as the writer has never seen any failure due to this cause. There are hundreds of stand-pipes in northern latitudes in America, where ice freezes to a thickness of 2 ft. or more, and yet failures from ice expansion are comparatively rare.

The top thickness of the dam, in the writer's judgment, should never be less than 4 ft., and 6 ft. or more is better, depending on the size of the stream and the height of the dam. This, however, is not capable of exact determination based on calculation, and in each case must be left to the judgment and experience of the designer.

It is unnecessary to discuss the theoretical considerations or design of the main section of the dam. These have been worked out most elaborately and carefully by Messrs. Wegmann, Brodie, Gregory, and others. When all the external forces are known, it is not difficult to design the dam with the most economical section to resist these forces safely. The main difficulty, however, is with the assumed data. Some of the sections which have been considered contain nearly twice as much masonry as others. If the smallest section is perfectly safe and can be built for several hundred thousand dollars less than the larger one, it is, of course, bad engineering to build the larger section. Where there is a doubt, and a mistake would cause loss of life as well as property, it is the absolute duty of the engineer to be on the safe side, but this then becomes a question of experience. One engineer, with abundant experience under all kinds of conditions, will make a design in which the safety is in his mind beyond question. Another engineer, however, who has read all these discussions, and who has not himself had this broad experience, would not dare to be responsible for such a design. Therefore, the question is a very serious one, and no simple solution appears to be possible.

Mr. Le Conte. L. J. Le Conte, M. Am. Soc. C. E. (by letter).—A survey for the purpose of determining the character of the foundation on which a dam is to be built is highly necessary in all cases; but too much faith should not be placed in the results thus obtained. The reason is plain and practical. Suppose the survey indicates favorable conditions, the question at once arises: "How do you know that these favorable

conditions will remain so *ad infinitum?*" The experience of the big concrete dam near San Mateo, Cal., built by the Spring Valley Water Company, of San Francisco, in 1888, is cited as an example. In the writer's opinion, this splendid structure is a lasting monument to common sense and sound engineering judgment. The foundation was stripped, examined carefully, and found to consist of a very fair quality of argillo—calcareous sandstone—full of seams and fissures, but all these were well filled with calcareous cement. The sandstone, of course, was porous, and, when exposed to water, soon became saturated. The concrete dam was built of the same sandstone crushed to small sizes and, of course, it was also porous. These facts being well-established, the engineer in charge, Mr. Herman Schussler, gave the dam such a cross-section as would stand with safety the water pressure from the reservoir as well as uplift on the entire base. This extremely safe load covers everything to be considered except ice pressure, but ice never causes trouble at and near San Francisco. Mr. Le Conte.

This dam had its severest test during the great earthquake of April 18th, 1906, which, together with the conflagration which followed in its wake, destroyed nearly half of San Francisco. The enormous ground fissure or geological fault passed through the chain of lakes built by the Spring Valley Water-Works, and, as luck would have it, passed close to the up-stream toe of the dam, cutting off the tunnel which delivered the main water supply to San Francisco. The earthquake cracked and shattered the bed-rock below the base of the dam, and gave rise to numerous new springs in the creek bed below the dam site; but, with the lapse of time, these have choked up and now discharge an insignificant quantity of water. This accident shows that even if one were absolutely sure of a perfect bed-rock, one could not depend on it in an earthquake. This dam, with 30 000 000 000 gal. of water behind it, stood the earthquake shock perfectly, and the writer believes that this remarkable result was due to its generous proportions and masterly construction.

The attention of practical engineers is called to the constant and ever-present danger to which the constructing engineer is always exposed and against which he cannot protect himself by any possible means, namely, imperfect materials and imperfect workmanship. These dangers are mentioned because of the unexpected results experienced with this great concrete dam, which are certainly worthy of record. It was not built with concrete *en masse*, but, on the contrary, in separate blocks of artificial stone, say, from 50 to 100 tons each, moulded in place. These blocks were interlocked and dovetailed together in such a way that it was confidently expected there would not be at any place a continuous seam or joint through the dam. The top of each constructed block in each layer varied in height so as to make broken lines, and each block was located so as to break joints

Mr. Le Conte. with the lower and upper layers. In addition, in each block were placed twisted iron rods with their ends sticking out to tie into neighboring blocks.

In spite of all this care and precaution, when the lake was filled with water, to the surprise of every one, a leak was discovered 90 ft. below the crest of the dam—where the concrete, from front to back, was nearly 100 ft. thick. This leak was not a simple "weeping," but, on the contrary, squirted out a considerable distance. It is proper to state, however, that it finally grew less and less, and ultimately became a mere "weep," overgrown with algæ, making a green spot on the back of the dam.

This leak, of course, was unimportant, but it serves to show how utterly absurd it is to assume that a masonry dam can be made absolutely water-tight. The writer believes that such perfection is wholly impracticable, if not impossible.

In regard to the curvature of the dam in plan: Mr. Schussler states: The cross-section of the dam would have a factor of safety of 5 to 1 if it were built straight across the valley, some 660 ft.; but it is on a curve up stream, the arch having a rise up stream of one-eight of the length, and the center line a radius of 724 ft. The factor of safety of the dam is greatly increased by curvature, and it will stand safely twice the pressure contemplated. The sound wisdom of this conclusion was amply tested by the earthquake of 1906; and, inasmuch as such shocks, of greater or less intensity, are to be expected in every State in the Union, they cannot be left out of consideration in the design of any dam of importance, where the lives and safety of many citizens are constantly in peril.

The cross-section of the dam was based on the following assumptions:

Total concrete masonry....................	1 329 tons.
Less gross uplift on base..................	1 050 "
Unbalanced weight..................	279 tons.
Total water pressure from the reservoir, at right angles to the face................	478 tons.

Both these forces act at a point on a vertical line through the center of gravity of the dam. The resultant force thus developed cuts the base of the dam just inside of the middle third, the angle which the resultant makes with the vertical at that point being about 50 degrees. Accordingly, the base, resting on bed-rock, is sloped downward toward the up-stream side, 10 ft. in 191 ft., which is the width of the base. This sloping bed-plane is broken by four vertical step jogs, of 2.5 ft each. This makes a rock trench, 191 ft. wide, 10 ft. deep at the lower end, and 20 ft. deep at the up-stream end, which

secures the dam against the possibility of sliding on its base, because of the very oblique resultant. Mr. Le Conte.

This assumption of a full hydrostatic pressure over the entire base of the dam, at first glance, seems to be unreasonable; but, in view of the uncertainty of the great ruling factors involved, the final summation of which cannot be predicted with anything like exactness, the assumption at once becomes conservative and entirely rational.

In addition to all this precaution, the dam in plan also has a curvature up stream which adds greatly to its stability and, at the same time, guards against the possibility of vertical fissures opening on the back of the dam because of the elasticity of the concrete masonry and the bed-rock itself.

The universality of the uplift over the entire base of a dam is shown by the history of the construction of the Assuan Dam across the Nile.* The only absolutely safe and sure course is to assume a full hydrostatic head over the entire base of the dam, then depress the up-stream toe so that it will be at least 6% deeper than the down-stream toe, and then terrace the foundation bed into four or five steps facing up stream to guard against sliding on the base. Some engineers also build a cut-off wall under the foundation bed. The propriety of this proceeding should be determined by test borings.

In conclusion, a comparison of the cross-sections of standard dams designed by Krantz and Professor Rankine for the same height, 185 ft., is interesting:

Krantz Dam...........................	12 015 sq. ft.
Rankine's Dam........................	12 728 " "
Schussler's Dam......................	18 970 " "

The writer thinks that the generous section adopted by Mr. Schussler has everything to commend it.

* *Minutes of Proceedings*, Inst. C. E., Vol. CLII, 1902-03.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

NOTES ON A TUNNEL SURVEY.
Discussion.*

BY MESSRS. LAZARUS WHITE AND FREDERICK C. NOBLE.†

LAZARUS WHITE, ASSOC. M. AM. SOC. C. E.—The speaker was connected for a time with the work described by Mr. Noble, took some part in the surveys, and is glad that their accuracy was verified so well by the actual meeting of the headings. He is now connected with tunneling which demanded a great deal of preliminary work of the kind described by Mr. Noble. It is probable that, due to the numerous shafts through which the City Aqueduct Tunnel is to bring Catskill water into New York City, the amount of alignment work necessary is unprecedented. Mr. White.

The twenty-four shafts are located, for the most part, in parks and at the intersections of city streets, and between them runs the tunnel. The most difficult part of the work, of which the writer is in charge, is that which is to be built under Contract 67. In order to avoid the condemnation of private property for rights-of-way, the tunnel is to be built under narrow streets on the lower East Side, crossing the East River to Brooklyn at the foot of Clinton Street. As an illustration: there are five angles in the tunnel between Shafts 20 and 21, both of these shafts being more than 700 ft. deep, and located on offsets to the main tunnel. Owing to the narrowness of the streets, there is a clearance of only a few feet at the corners.

The speaker does not believe that elaborate apparatus is now necessary for accurate base-line traversing, or for triangulation in connection with tunnel alignment. Most of the taping on the City Aqueduct was made with the simple apparatus shown by Fig. 1, Plate XXXIII. In addition to the usual equipment of levels, tape, sight-rods, etc., it was necessary to have only two tables, constructed of 4-in. pipe, and an outfit consisting of turnbuckle, spring balance and stretcher, as shown. This additional apparatus cost only a few dollars. The tapes were standardized according to the methods shown on

*Continued from March, 1912, *Proceedings*.

†Author's closure.

Mr. White. Fig. 5, and with the apparatus, of the Topographical Bureau of The Bronx. This apparatus is all that can be desired, and with it the tape can be readily standardized to the utmost degree of accuracy.

Fig. 5 also shows the tables used, and a copy of the actual field notes for one run. These tables are very simple, and were prepared for the purpose of eliminating the error in the application of temperature corrections, each tape length being calculated for its actual distance at certain temperatures, with suitable pull and catenary. The tables also contain a correction in case the tape is supported. After adding up the tape lengths, it was necessary to make only slope corrections, obtained from the level runs. These slope corrections are always in one direction, and, therefore, cannot be applied with the wrong sign.

Before taping, angle-points of traverses were established in the streets. Where the traffic was light, the points were taken directly on the sidewalk and used with an elevated target, shown on Fig. 1, Plate XXXIII. This target proved to be convenient, as it could be supported securely above the heads of pedestrians. In places where the traffic was heavy, or for long lines, elevated points on buildings or other structures were selected and keel-marked, and angle-points were obtained by successive trials between the elevated points. These elevated sights proved to be of great help; intermediate points on the line were established by running toward them, and, in addition, the angle work was done with speed and was not obstructed by traffic. Angles were measured by repeating six times with telescope direct, reading the first, fourth, and sixth readings; then measuring the supplementary angle in the same way, with telescope reversed, the averages from the first, fourth, and sixth readings checking within from 3 to 5″, and the sum of the angle and supplement being 360° within 5″. When the results exceeded these limits, additional work was done, and both the angle and its supplement were measured twelve times—six direct and six reverse.

Taping was done with the apparatus shown, the sequence of operations being as follows:

(1) Rear turnbuckle adjusts index of tape to pin on table;

(2) Stretcher puts on slight tension, aligning tape over keel-marks on sidewalk, or sighting along line;

(3) Head chainman meanwhile places tripod under tape to solid bearing, marks keel triangle and keel station on the ground;

(4) Stretcher puts on the proper tension, and pin is stuck opposite index;

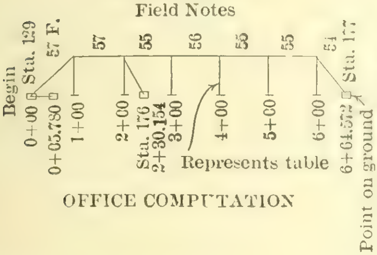
(5) Tension is released, rear turnbuckle is unhooked, fore chainman goes ahead, sliding tape on ground, rear chainman brings his box and table (A) with him to the stretcher, who has been guarding the forward table (B); the stretcher then goes ahead with table (A) to his new station, and operation is repeated.

FIG. 1.—APPARATUS USED FOR BASE-LINE TAPING, FOR CITY TUNNEL, CATSKILL AQUEDUCT.

FIG. 2.—APPARATUS USED FOR BASE-LINE TAPING, RONDOUT PRESSURE TUNNEL.

Mr. White.

FORWARD RUN
Field Notes



OFFICE COMPUTATION

Sta. 129 to 177

Point	Diff. Elev.	Slope Corr.	Temp.	Distance
129 0+00	(0.20)	(.004)		(05.780)
175 0+05.780	0.48	.001	57	100.010
1+00	0.96	.005	57	100.011
2+00	(0.39)	(.003)		(30.157)
176 2+30.154	1.06	.006	55	100.009
3+00	0.62	.002	56	100.010
4+00	0.80	.003	55	100.009
5+00	0.60	.002	55	100.009
6+00	1.69	.023	54	64.578
177 6+64.572				
		.042		664.636
			less	.042

129 to 177 = 664.594
129 to 175 = 05.776
175 to 176 = 224.393
176 to 177 = 434.425

Intermediate plus measurements data shown thus: (0.004) Slope corrections are taken from printed table.

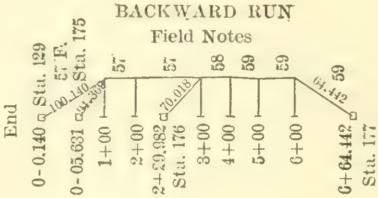
TAPE LENGTH TABLE

Tape unsupported between ends

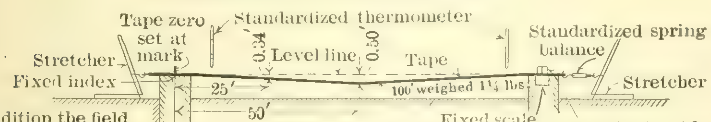
Temp. Fahrenheit	Tape No.6 30 lbs pull			
	0-25	0-50	0-75	0-100
0	24.993	49.988	74.981	99.973
20	24.997	49.994	74.991	99.986
30	24.998	49.997	74.996	99.993
32	24.999	49.998	74.997	99.994
34	24.999	49.999	74.998	99.995
36	24.999	49.999	74.999	99.997
38	25.000	50.000	75.000	99.998
40	25.000	50.001	75.001	99.999
At two degrees intervals up to 90				
86	25.007	50.016	75.023	100.029
88	25.008	50.016	75.024	100.031
90	25.008	50.017	75.025	100.032
100	25.010	50.020	75.030	100.038
For Tape supported add	.000	.001	.003	.007

For intermediate distances the correction is proportional.

BACKWARD RUN
Field Notes



STANDARDIZING BASE LINE TAPE



In addition the field thermometers and balances are compared with the standard.

First: Standard tape is stretched and scale read
Second: Tested " " " " " "

Vernier is set by screw motion opposite tape index and scale read through microscope to $\frac{1}{10\,000}$ ft.

From the above, the supported length was computed. Then accurate ¼ tape lengths were laid out on level floor inside a building and the errors at 25, 50 and 75 foot graduations were found for tape supported and unsupported. The sag correction results were later closely checked by formula; Sag $= \dfrac{Lw^2 l^2}{24 t^2}$

BASE LINE TAPPING
CITY TUNNEL
(CONTRACT 67)
CATSKILL AQUEDUCT
NEW YORK
BOARD OF WATER SUPPLY.

FIG. 5.

Mr. White. After the taping was completed, a double line of levels was run over the triangles obtained during Step (3). The note-keeper recorded the temperatures and kept graphic notes, showing exactly how the tape was stretched along the ground. These graphic notes are reproduced, in part, on Fig. 5, and were of great help to the levelmen and in the computations, making it very easy to apply the proper corrections. Forward and backward runs readily checked one another in the field, as the slopes were the same and corrections for average differences of temperature could be readily made.

All the shafts were connected by closed traverses, as indicated on Fig. 6, from which it will be seen that the errors of closure in these traverses were very small. In addition, an entirely independent check was obtained by tying in the Smith-Gray Tower, in Brooklyn, and the Metropolitan Life Tower, in Manhattan, the co-ordinates of both these points being established by Government traverses. These two points, about 20 000 ft. apart, checked within 1 ft., although the co-ordinates of the Metropolitan Life Tower are not guaranteed by the Government to be correct within 1 in 25 000. The traverses as originally run out were not generally over the center line of the tunnel, but from them the exact positions of the P. I.'s of the tangents vertically over the tunnel were computed. Between these P. I.'s distances were taped and angles turned, as a final check on the computations in the original field work. These were found to check closely with the computed lengths and angles.

The East River was crossed by the triangulation system shown on Fig. 6, only a few days' work being necessary. The Water Street base line was first taped, the Brooklyn base line being computed and found to check within 0.08 ft. when afterward taped. The angles were read by repetition in a set of ten direct and then a set of ten reverse; the first, fourth, seventh, and tenth angles of each set being read and averaged, to insure against slipping plates and wrong readings. The angles were read on March 13th and 14th, 1911, under fair conditions. In every case the signals sighted at were solid points—parts of the building structure—except at Corlear Park, where a range pole was supported by a tripod. There were two main triangles with a common base in Manhattan to locate two points in Brooklyn at the extremities of the Brooklyn base.

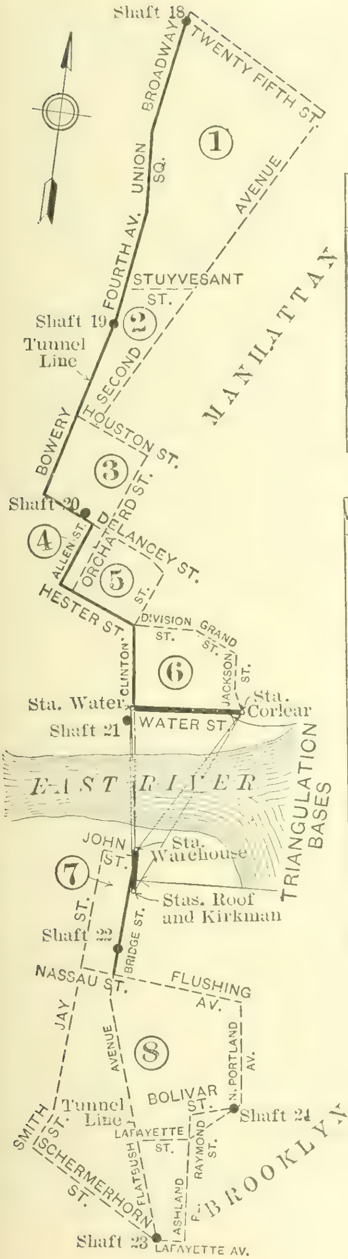
A definite idea of the time taken by the work indicated on Fig. 6 is shown by the following: (The field work was done between March 1st and May 11th, 1911, including the triangulation across the East River.)

Base-line taping done = 118 000 ft.
Base-line traverse run = 65 000 ft.

Number of 7-hour days:

Worked on taping = 12
Worked on traversing = 42

Mr. White.



BASE LINE TRAVERSING
CITY TUNNEL
(CONTRACT 67)
CATSKILL AQUEDUCT
NEW YORK BOARD OF WATER SUPPLY.

ERROR OF CLOSURE IN TRAVERSES

TRAVERSE NUMBER	NUMBER OF ANGLES	ERROR	LENGTH TRAVERSE MILES	ERROR OF CLOSURE
1	10	0°00′20″	2.4	1:51 000
2	8	0°00′11″	1.2	1:42 000
3	4	0°00′10″	1.1	1:53 000
4 & 5	10	0°00′12″	1.0	1:47 000
6	7	0°00′04″	1.1	1:105 000
7	6	0°00′01″	1.0	1:85 000
8	11	0°00′20″	2.6	1:190 000
7 & 8	15	0°00′19″	3.4	1:395 000
Triangulation	Brooklyn base, computed from Manhattan base, differs 0.083 foot from measured distance.			

TAPING NOTES
Some of the Shorter Courses Omitted.

TRAVERSE NO.	STATION FROM	STATION TO	DISTANCE TAPED FORWARD	BACKWARD	THIRD RUN	AVERAGE
1	M.7	M.4	2 293.655	2 293.658		2 293.656
	M.4	M.1	1 198.023	1 198.003		1 198.013
	160	49N	1 220.503	1 220.541	1 220.610	1 220.551
	M.12	M.9	1 801.164	1 801.173		1 801.168
	M.9	M.8	860.825	860.799		860.812
	M.8	M.7	595.462	595.472		595.467
2	198	195	762.321	762.289		762.305
	195	196	328.311	328.312		328.311
	196	143	937.583	937.592		937.589
	150	M.1	420.809	.420.825		420.817
	199	198	766.836	766.852		766.844
3	192	175	1 480.431	1 480.459		1 480.445
	129	133	357.189	357.193		357.191
	133	137	837.481	837.503		837.492
	137	196	1 486.777	1 486.761		1 486.768
	195	192	1 014.542	1 014.541		1 014.542
4	119	125	228.380	228.377		228.378
	125	126	501.907	501.918		501.912
	126	127	366.442	366.431		366.436
	127	128	256.034	256.046		256.040
	128	129	189.654	189.653		189.654
5	175	177	658.818	658.843		658.831
	177	212	545.804	545.805		545.804
	212	210	985.584	985.583		985.584
6	Corlear	Water	1 881.799	1 881.796	1 881.815	1 881.803
	107	110	692.772	692.770		692.771
	114	171	993.950	993.937		993.944
	171	173	798.080	798.084		798.082
	173	174	618.975	619.032	619.004	619.002
	174	Corlear	368.908	368.894		368.901
7	32	35A	460.764	460.764		460.764
	35A	46	1 657.111	1 657.119		1 657.115
	46	60	546.539	546.534		546.536
	60	61	1 294.971	1 294.940		1 294.956
	61	64	818.494	818.506		818.500
	64	32	530.446	530.441		530.444
8	64	67	1 842.689	1 842.691		1 842.690
	70	72	574.344	574.328		574.336
	72	77	2 502.743	2 502.876		2 502.810
	77	6	595.018	595.992	595.025	595.012
	6	7	441.300	441.327		441.314
	7	10	1 642.121	1 642.154		1 642.138
	10	11	601.916	601.927		601.922
	11	15	325.933	325.946		325.940
	15	19	1 729.240	1 729.229		1 729.234
	19	64	2 808.619	2 808.563		2 808.591

FIG. 6.

Mr. White. The time spent on base-line traverse includes all miscellaneous work, such as locating building corners, leveling, secondary traversing, etc.

It is to be noted that this work included the accurate location of building lines and the intersections of all streets under which the tunnel is to be built, this information being necessary in order to determine the clearances.

The lines to be taped were laid out by transit ahead of the taping by putting marks on the sidewalk at approximately 50-ft. intervals, or, when there was a good foresight, the line was sighted in, either by the fore- or rear-chainman, and was checked at line-points existing at every block. This method leads to little error when it is considered that a 100-ft. tape length must be offset 0.45 ft. before the distance is in error 0.001 ft., and offset 0.63 ft. before the distance is in error 0.002 ft., or 1 in 50 000.

With the method just described, the working speed, including delays, was very little less than 2 500 ft. an hour, even on crowded streets. Through the use of the elevated sights, as described, crowds did not hinder the aligning. A 100-ft. tape length was regularly taped in 90 sec., including the time taken to move ahead to get ready for the next length, and a speed of 4 500 ft. an hour has been made. The essentials leading to speed are the short time (from 2 to 5 sec.) that the tape is actually stretched to make the measurement, and the sliding of the tape along the ground in moving ahead. On Sunday, April 23d, 1911, the party taped and ranged out the line from Orchard Street, along Delancey Street, along the Bowery to Fourth Avenue, to 15th Street, and return—a distance of 14 500 ft.—in 6¼ hours.

The principal source of error in taping with ordinary steel tape such as used, however carefully standardized, is due to the temperature of the tape not corresponding to that of the thermometers. This source of error can be practically eliminated with the "Invar" tape, which is made of an alloy of iron having a coefficient of expansion only one-twenty-eighth of that of steel. These tapes were originally made in Europe, but are now made in the United States, and cost about $1 per ft. with graduations every foot for 50- to 200-ft. lengths. They are well worth the increased cost where much accurate taping is required. The "Invar" tapes are soft, however, and require large reels and careful handling.

The method of taping described is essentially the same as that used up the State on base-line taping in connection with the work of the Board of Water Supply, with the exception that, on account of the rough ground, high tripods were used. The tapes were hand-stretched without the use of stretcher or turnbuckle. This is shown on

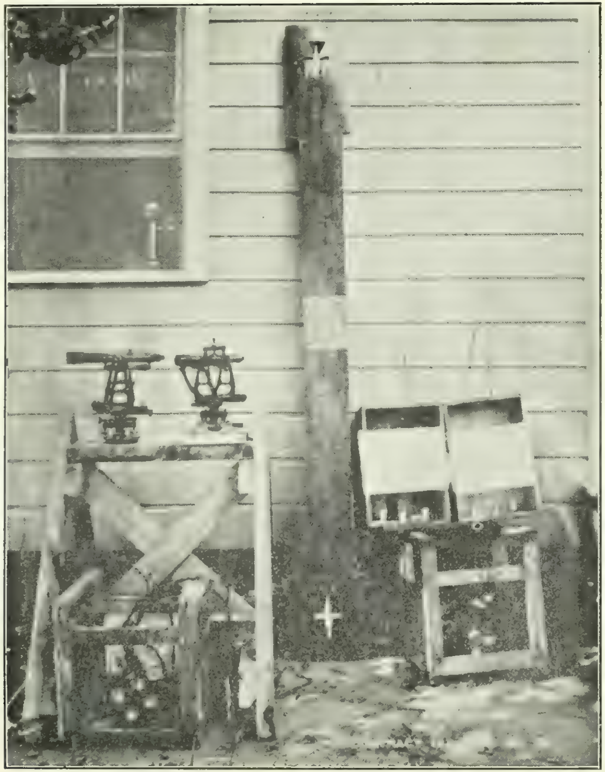


FIG. 1.—SIGHTING BOARD AND APPARATUS USED FOR LINE DROPPING, RONDOUT PRESSURE TUNNEL.

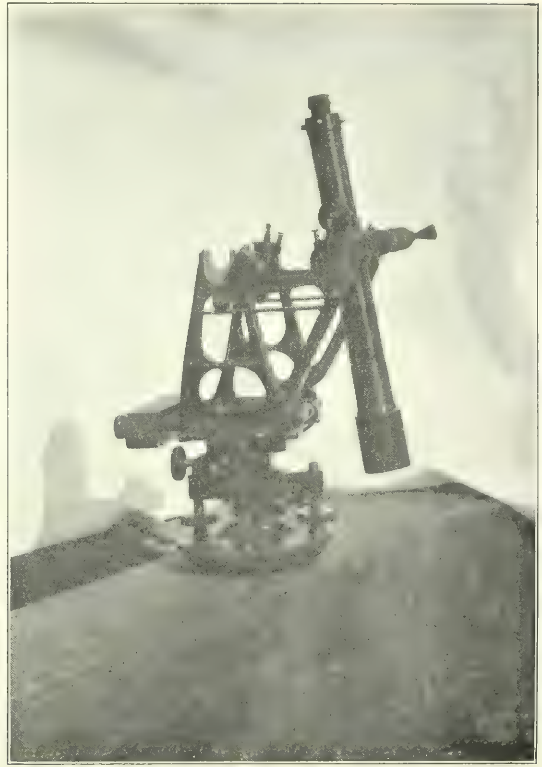


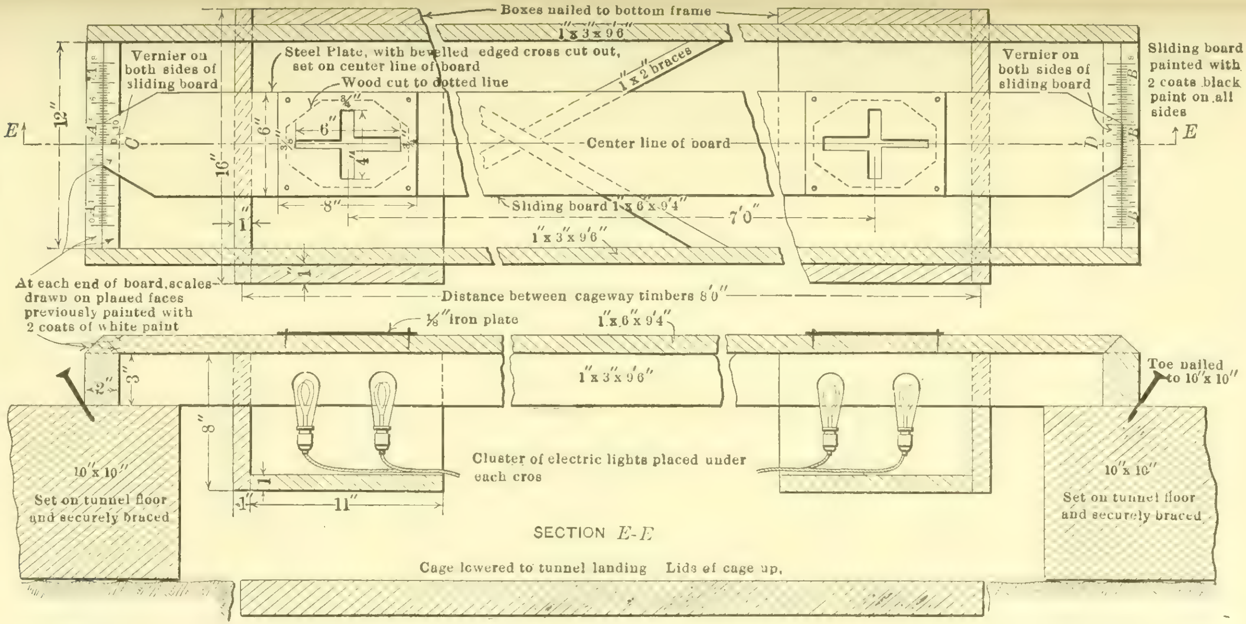
FIG. 2.—VERTICAL SIGHTING TRANSIT USED FOR LINE DROPPING, RONDOUT PRESSURE TUNNEL.

Fig. 2, Plate XXXIII. Here, also, the tape lengths were always 100 ft., the data for slope corrections being obtained by simultaneous leveling on top of the tripods, the temperature of the tape being observed at the same time. With this apparatus, high speed was also made, a distance as great as 5 000 ft. being taped in both directions, over rather rough country, in one day. With this method, to-and-fro taping was computed in the field, so that it was at once known whether a third taping would be necessary. Mr. White.

In dropping lines down the shafts, the apparatus and methods used were very similar to those described by Mr. Noble. The shafts were much deeper, however, being as great as 700 ft., and even 1 100 ft. at the Hudson siphon. In this work it was found that the most important feature is to perfect the mechanical details, so that when the party goes out the apparatus will be in readiness for quick work. At first the shafts were provided with alignment boxes, through which wires for line-dropping were suspended. These proved to be a source of considerable worry, as one could never tell whether or not the line was touching the side of the box. Later, they were removed, as it was found better to drop the wires in the open. The chief source of error in work of this kind is the likelihood of the fouling of the wires. It was found that it was not necessary to occupy the shafts more than two or three Sundays in order to obtain lines sufficiently accurate to run between shafts 4 000 or 5 000 ft. apart and meeting within less than a few tenths of a foot. This was appreciated by the contractors, as the engineers interfered with the shaft only a few days in the course of the work.

On the Rondout and Wallkill Siphons a vertical sighting instrument was used with considerable success. This instrument was devised to drop the line directly down the shaft by sighting with a telescope arranged to be mounted on a bracket so as to clear the plates when in a vertical position. The instrument was built by Berger, from parts used in previous models, and was excellent for the purpose, except that it was subject to lateral movement on the wyes, there being no positive adjustments to prevent this. This instrument permitted a method entirely different from that generally used, and provided an independent check sufficiently good to justify running out lines with only two sets of observations—one obtained by line-dropping with wires, and the other with the vertical sighting instrument. The method used with this instrument is shown clearly by Fig. 7. It was found that the results obtained depend very largely on the mechanical details, lighting, ventilation of shaft, etc. Fig. 1, Plate XXXIV, shows the sighting board and apparatus for dropping line down the shaft by vertical sighting, as used on the Rondout Tunnel. Fig. 2, Plate XXXIV, shows the vertical sighting transit.

Mr. White.



Operation of Board for one Complete Set of Readings: Nail bottom frame approximately on center line, and slide board between Scales *A* and *B*. Set board 10 times with instrument on top direct, and 10 times reversed; then turn board over and repeat (10 times direct and 10 times reversed.) The relation of scales below is found by a transit set near board and on line of two fixed points on tunnel scales, then sight either tunnel scale and set Vernier Board on line, getting readings for scales *A* and *B*.

VERNIER BOARD
FOR
SHAFT LINE DROPPING

NEW YORK
BOARD OF WATER SUPPLY

FIG. 7.

Mr. Noble.

FREDERICK C. NOBLE, M. AM. SOC. C. E. (by letter).—The method of measuring base lines described in the discussion is admittedly more accurate than the one described in the paper, yet the latter gave very satisfactory results. Since the tunnel line had curves between shafts, the triangulation base was measured to the principal end that the headings should meet with the minimum error in line; and, to this same end, equal consideration had to be given the tunnel measurements carried forward from the shafts. Compensating errors, such as inaccuracies in individual measurements resulting from the use of ordinary apparatus, are to be distinguished from systematic errors, which do not thus balance out. Known systematic errors can be allowed for, but there will be systematic errors of unknown extent peculiar to the method. Provided the same method of measuring is used in the tunnel as for the base line, the sum of the systematic errors peculiar to the method should be of the same sign, and proportional to the distances measured, thus leaving the final result unaffected. The best method of measuring a triangulation base for tunnel purposes should be a simple one which proves to be the most readily applied to measuring in the tunnel.

In all measuring and alignment operations a large number of repetitions is the best way of reducing the effect of unavoidable individual errors. How far this should be carried in any case depends on a proper recognition of the importance of the final result as compared with the importance of the means taken to secure it.

Co-ordinates were used for computation purposes in special cases where conditions warranted, but there was no occasion to make their use a general feature of the survey work. All topography was readily referable to the principal lines from which the working tunnel lines were derived.

In closing, it is necessary to correct the misapprehension, developed in the discussion, that the intersection of the tube tangents was made to fall at a triangulation point. The intersection point was first located and later adopted to serve as a triangulation point; and its use as such had the advantage of reducing the number of necessary survey operations.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SPECIFICATIONS FOR THE DESIGN OF BRIDGES AND SUBWAYS.

Discussion.*

BY MESSRS. S. M. SWAAB, J. B. FRENCH, AND HENRY B. SEAMAN.†

S. M. SWAAB, M. AM. SOC. C. E. (by letter).—The live load which is transmitted through the earth from the street surface to the subway roof is of varying intensity, depending, in the first place, on the distribution of the load on the surface, secondly, on the number and arrangement of the underground structures, thirdly, on the depth of fill on the roof, and lastly, on the cohesion of the soil. This latter quantity is usually negligible, for, when the structure is built by cut-and-cover method, there is no cohesion to speak of in the back-filled earth, although it is possible that, as the soil becomes compacted, this condition may be developed. There is doubtless a greater percentage of the load transferred from the surface to the subway roof where the fill on the top of the structure is slight than where the depth is considerable, but what portion of the load is transferred, and in what manner it is transferred, are the facts to be determined. The writer desires to know in what way it is proposed to transfer the local concentration of 100 k., on four wheels, 12 ft. between axles and 8 ft. gauge, to the subway roof, and also why a concentrated load without regard to any limitations as to area covered (as is stated in the proposed specification) may be considered as distributed over an area of 4 sq. ft. and thence through the earth on a slope of ½ to 1. Mr. Swaab.

J. B. FRENCH, M. AM. SOC. C. E. (by letter).—These specifications are confined entirely to matters of design, and contain many valuable data, well arranged and co-ordinated for the designer's use. The author's avowed purpose has been to prepare a single set of general Mr. French.

* Continued from February, 1912, *Proceedings*.

† Author's closure.

Mr. French. specifications, which shall apply not only to bridges for all classes of traffic, with spans from 16 to 1 600 ft., but also for rapid transit subways, and for all the various materials of construction entering into these structures.

For this purpose, the specified stresses for steelwork, which is most prominent in the specifications, are based on an "allowable static strain" of 20 000 lb. per sq. in. of net section, and all moving loads, regardless of their character or method of application, are increased according to the "static equivalent," or impact formula,

$$S = 125 - \frac{1}{8} \sqrt{2\,000\,L - L^2},$$

where L = length, in feet, of the applied loading which produces maximum stress in the member.

The general discussion which followed a similar paper* presented by Mr. Seaman in 1899 undoubtedly had much to do with the uniformity which has been attained since that time in general specifications for steel structures. The advantages of this uniformity are obvious, but it is somewhat doubtful whether the greater generalization suggested in the present paper would be equally advantageous.

Before discussing this question, therefore, it seems pertinent to state briefly what has been accomplished in this direction during recent years.

By organized and intelligent co-operation on the part of engineers representing both manufacturers and purchasers, and others not attached to either group, in the Committee on Steel Structures of the American Railway Engineering Association, specifications for a single grade of structural steel have been prepared, which have since been adopted, with slight modifications, by the American Society for Testing Materials as its "Standard Specifications for Structural Steel for Bridges." The latter society has also adopted "Standard Specifications for Structural Steel for Buildings," defining another single but somewhat inferior grade of material.

Through the efforts of this same committee, the "General Specifications for Steel Railroad Bridges," incorporating the specifications for structural steel previously mentioned and including detailed requirements for design and workmanship, have also been adopted by the American Railway Engineering Association, in which the unit stresses are based on 16 000 lb. per sq. in. of net section for axial tension, and live-load stresses (from railroad traffic only) are increased by a "dynamic increment" determined by the commonly used impact formula, $I = S \frac{300}{L + 300}$, where L has the same meaning as in Mr. Seaman's formula.

* *Transactions*, Am. Soc. C. E., Vol. XLI, p. 140.

These Railway Association specifications have been quite generally adopted, in whole or in part, by leading railroads, and the 16 000-lb. unit stress has also been adopted for highway bridges and for the steelwork of buildings by such authorities as G. F. Swain, M. Am. Soc. C. E., in the "Specifications for Bridges Carrying Electric Railways," written for the Massachusetts Railroad Commission, and by C. C. Schneider, Past-President, Am. Soc. C. E., in his specifications for "Structural Work of Buildings."* Mr. French.

In these previous efforts toward uniformity, the adopted standard grades of structural steel and an allowable unit stress of 16 000 lb. per sq. in. in axial tension, therefore, appear to be closely associated, but each has been confined to specifications for ordinary structures, the steelwork for which is usually wanted quickly and at the ordinary market price.

It can be fairly claimed that rolled or fabricated material which complies fully with the foregoing specifications, undoubtedly represents the best average product of modern mills and shops, and that the purchaser of such material will get the quickest deliveries and the lowest prices.

It does not follow, however, that this standard material, which is manufactured to meet the average requirements for ordinary structures, is equally suitable for more particular and special purposes, such as the main members in very long bridges, in which the dead weight has to be reduced as much as possible; and, if special material is required, special rules of design and special requirements for workmanship and fabrication will necessarily be required also.

The writer thinks, therefore, that further generalization of specifications for structural steelwork should include the adoption of these standard grades of structural steel and of unit stresses based on 16 000 lb. per sq. in. for axial tension, and that they should be confined to the ordinary structures for which such material and stresses are suitable.

In regard to impact formulas: It may be of interest to note that the formula, $I = S \frac{300}{L + 300}$ used in the specifications of the American Railway Engineering Association, was first suggested by Fred. Thompson, M. Am. Soc. C. E., and was first published in the bridge specifications of the Southern Railway Company, issued in 1894, as a substitute for the formula, $I = S \left(0.10 + \frac{220}{L + 240} \right)$, used by Mr. Schneider in the revised Pencoyd specifications of the same year. On account of its greater simplicity, and the close similarity of the values given to those derived from the Pencoyd formula, Mr. Schneider substituted it for the latter in his specifications of 1895, and used it in his

* *Transactions*, Am. Soc. C. E., Vol. LIV, p. 490.

Mr. French. later specifications for the American Bridge Company. It is frequently referred to, therefore, as the "American Bridge Company" formula.

It should be kept in mind, however, that, when the Pencoyd specifications were published in 1887, and for years afterward, data, derived from actual measurements on existing bridges under American conditions of track, rolling stock, and train speeds, were almost entirely lacking, as was stated by Mr. Schneider in his discussion* on the "Life of Railroad Bridges" in 1895; and, while logical scientific grounds and excellent reasons for using an impact formula and uniform working stresses were clearly stated in that discussion, no claim was made that the formula was scientifically accurate or final, as is shown by the following statement:

"If future experiments should prove that the coefficients for impact adopted are too large, they can be easily corrected, which, however, would not affect the system, but would only involve a change of the numerical values of the coefficients."

In 1887, and, to a diminishing extent, up to within the last ten years, solid ballasted concrete floors for railroad bridges were rarely used, and the wooden cross-ties delivered the live loads directly into the steel structure. The rails, ties, and guard timbers of the old type of floor, together with the steel stringers and floor-beams for ordinary single-track plate girders or truss spans, weighed less than 1 000 lb. per lin. ft. of track, while the rails, ties, ballast, concrete, and steelwork in the floor of the ordinary plate-girder spans with the solid ballasted floors, now commonly used in grade-crossing eliminations in cities, frequently have a total weight of more than 5 000 lb. per lin. ft. of track.

With any type of floor varying comparatively little in weight per foot for spans of different lengths, the effect of the suddenness of the application of the load to the girders or truss members can reasonably be considered as inversely proportional to the length of the structure or of its loaded portion. The weight, inertia, and cushioning effect of the construction or medium through which the live load is transmitted to the member, however, should certainly be taken into account in the determination of the proper increment to be added for impact or to produce the "static equivalent."

The most recent and most extensive series of impact tests on railroad bridges are those made by the sub-committee of the Committee on Steel Structures of the American Railway Engineering Association. These tests are described† very fully, and the following statements in the report of the sub-committee have a direct bearing on this

* *Transactions*, Am. Soc. C. E., Vol. XXXIV, pp. 328-335.

† *Bulletin* No. 125, American Railway Engineering Association, July, 1910.

Mr. French.

discussion: On page 13, in speaking of the method of conducting the tests, the report states:

"Little difference was noted in the results at various speeds below 15 miles per hour, and, in general, the results at 10 miles per hour may be considered as practically equal to static stresses."

This seems to show that no increase is necessary to produce the static equivalent of stresses from such moving loads as pedestrians and vehicles passing over bridges or subways. On pages 32 and 33, under "Summary of Results," the following statements are made:

"The maximum impact percentage, as determined by these tests, is closely given by the formula,

$$I = \frac{100}{1 + \frac{l^2}{20\ 000}},$$

in which I = impact percentage and l = span length [and from which the maximum value for I is 100% when $l = 0$].

"The effect of differences of design was most noticeable with respect to differences in the bridge floors. An elastic floor, such as furnished by long ties supported on widely spaced stringers, or a ballasted floor, gave smoother curves than were obtained with more rigid floors. The results clearly indicated a cushioning effect with respect to impact due to open joints, rough wheels and similar causes. This cushioning effect was noticed on stringers, floor beams, hip verticals and short-span girders."

As bearing on this question of the cushioning effect of solid ballasted floors, the following statement, by the late G. H. Thomson, M. Am. Soc. C. E., in 1892, speaking of his experience on the New York Central Railroad, seems pertinent:*

"A considerable number of abutments and piers hammered out by deck plate bridges of small span, coming within the experience of the writer, will require an outlay to rebuild them equal to ten times the cost of new solid floor bridges; the injured masonry, however, will sustain the solid floor bridges, though not equal to the task of sustaining the old-fashioned plate bridges."

A. F. Robinson, M. Am. Soc. C. E., Bridge Engineer of the Atchison, Topeka and Santa Fé Railroad, in a paper† before the Western Society of Engineers in 1904, also stated that solid ballasted floors had been built under his direction to replace long timber ties resting on shelf-angles in half-through plate-girder spans, and that, notwithstanding the increased weight of the floor and the greater stresses, the deflection and vibration of the old steel girders were less than before the heavier floor had been put in.

---

* *Transactions*, Am. Soc. C. E., Vol. XXVII, p. 507.

† *Journal*, Western Soc. of Engrs., Vol. X, No. 3, p. 253.

Mr. French. On the strength of these statements and similar testimony, the writer, some years ago, adopted the following rule in the design of railroad bridges carrying such floors:

"In the case of main girders or trusses, and their supports, carrying fully ballasted track, one-half the dead-load stress shall be subtracted from the full live-load stress, before applying the impact formula."

In the design of the floor itself, he has treated the engine concentrations as uniformly distributed over a length equal to the distance between the axle centers and over a width of 10 ft., plus 100% for impact (that is, for E-50 loading, the floor is designed for a uniformly distributed load of 1 000 lb. per sq. ft., including impact). Particular care was taken, however, to have the concrete encase the steel floor-beams and lower girder flanges thoroughly, and to bond the concrete and the steelwoork together as effectively as possible, for the purpose, not only of reducing impact and making the two materials work together, but also of deadening the noise; and the structures thus designed are giving a good account of themselves in service.

The only provision in Mr. Seaman's specifications relative to structural steelwork embedded in concrete is the following: "When beams and girders are embedded in concrete, the allowable flange strain may be increased 25 per cent."

This general type of construction is now used extensively, and occupies a distinct position of its own, intermediate between ordinary structural steelwork and reinforced concrete; and, in the writer's opinion, its design is worthy of careful and detailed attention. In the first place, such construction should be designed and built so that the concrete will protect the steelwork from corrosion permanently and effectively, and, if that is accomplished, the author's requirement in regard to "minimum section" can be properly revised to permit the use of $\frac{1}{4}$-in. material. In the second place, there seems to be no sufficient reason why this composite construction should not be designed so as to make the concrete work with the steel in resisting compressive stresses. They must, in fact, work together in this way, unless the bond between them is destroyed, and steel compression flanges designed by the author's rules can never receive the specified stresses unless the encasing concrete is crushed or slips on the steel.

One great advantage which this type has over ordinary reinforced concrete construction is illustrated in its use for bridges carrying streets over steam railroad tracks, where the maintenance of uninterrupted railroad traffic is essential. The structural steel frame can be erected at night or between trains, and is immediately available to support the forms and carry the weight of the plastic concrete; and, by the time it is necessary for the bridge to carry full live and dead

loads, the concrete has set, forms a working part of the structure, and also serves as the most effective means yet devised to protect the steelwork from locomotive gases. Mr. French.

The writer prefers, therefore, as far as practicable, to treat a plate girder embedded in concrete exactly as he treats a so-called unit frame of rods or other steel reinforcement embedded in a reinforced concrete beam; in other words, to proportion the steel in the tension flanges for the maximum total load at the regular tensile unit stress (preferably 16 000 lb. per sq. in. of net section); to proportion the web-plate to carry all shearing stresses; and to proportion the steel in the compression flanges to carry, unaided, all stresses from initial loads which can occur before the concrete has set, and rely on the concrete, as a composite part of the beam, to resist all subsequent compressive stress. This practice, of course, requires particular care in order to insure an effective bond between the concrete and the steel, and makes careful workmanship and thorough inspection a necessity, but not to a greater degree than with reinforced concrete.

The roof of a subway station with a fairly deep earth cover, where spans are too long for ordinary reinforced concrete slabs, also presents conditions admirably adapted to this method of design. The maximum initial load which the steel girder has to carry unaided, consists of the weight of the forms and the plastic concrete only, all additional load, both dead and live, being applied after the concrete has set.

A six-track railroad bridge of short, shallow spans, designed in this manner, and carrying both the heavy freight and high-speed passenger traffic of an Eastern trunk-line railroad, with only 6 in. of ballast under the ties, has been in service considerably more than a year, and is giving entire satisfaction.

In regard to the design of reinforced concrete: In Mr. Seaman's specifications, the maximum tension in the steel is fixed at 20 000 lb. per sq. in., the same as for structural steel, but it is stated that "from 0.70 to 1.50% of steel gives the usual economical sections." These percentages, coupled with a specified "maximum compression in concrete of beams" of 600 lb. per sq. in., a ratio $\frac{E_s}{E_c} = 15$, and straight-line deformation, mean that the corresponding unit tensile stress in the steel will vary from about 15 600 to 9 600 lb. per sq. in. In this case, also, the commonly used unit stress of 16 000 lb. per sq. in., therefore, would seem more suitable than the 20 000 lb. specified.

In the specifications for reinforced concrete, also, the clause, "Beams and slabs shall be calculated as simply supported, but rods shall be placed in compression flanges over supports, to prevent cracking," appears to put an undesirable check on the designer. Undoubtedly, this clause was written to fit the reinforced concrete cross-section so uniformly used in the New York subways, namely,

Mr. French. what may be described as a box-section, the sides of which are designed as discontinuous single-span slabs, arbitrarily reinforced at corners and over supports sufficiently "to prevent cracking," no method being prescribed by which the size or length of such reinforcement may be determined.

The writer believes that the cross-section of a subway, like that of a tunnel or sewer, if built of reinforced concrete, should be designed to be as nearly structurally continuous as possible, and that the conditions governing the execution of such work are too varied to make the use of a uniform type of cross-section, or such a rule as the one quoted, desirable in a set of general specifications.

On the other hand, rules of design for reinforced concrete will prove of little effect in securing thoroughly good construction unless the general procedure to be followed in construction is anticipated and controlled by the engineer responsible for the design. In structural steelwork, such general procedure can be taken for granted, but not in reinforced concrete. The writer, therefore, would suggest the following additional clause as desirable in general specifications for reinforced concrete design:

"The location and shape of the joints at which reinforced concrete work can be suspended, shall be determined by the designing engineer and clearly indicated on the plans, and the concrete for any one of the portions into which the construction is thus divided, shall be deposited in one continuous operation."

This, of course, assumes that the work will be thoroughly and continuously inspected to insure the effective carrying out of the designer's intention.

In regard to the design of timber structures, the author's specifications depart radically from common practice, as they require that "all live strains must first be increased to equivalent static strains by formula" (which formula for spans under 20 ft. requires an addition of more than 100%), and the specifications only increase by 50% the ordinary allowable stresses, which have been commonly used without considering impact. This departure can be shown very strikingly by investigating the strength of an ordinary railroad timber trestle, as commonly built for E-40 loading, with bents 12 ft. 6 in. between centers, and two Georgia pine stringers, 9 by 16 in., under each rail, a construction which has amply proved its efficiency. Without considering impact, the calculated stress in the outer fiber of these stringers, in bending, is about 1 400 lb. per sq. in., but with impact included, according to the author's formula, this stress is 2 730 lb. per sq. in., or more than 50% in excess of the 1 800 lb. allowed in the specifications. Notwithstanding this, the following note is inserted under the tabulated "Allowable Static Strains for Timber":

"In this table the values for allowable static strains for timber are 50% greater than those formerly used for miscellaneous loading, and 100% greater than would be allowed for a moving load suddenly applied." Mr. French.

The specifications should certainly be revised as regards the design of timber structures, which are usually of short span.

Henry B. Seaman, M. Am. Soc. C. E. (by letter).—In 1899 the writer presented to the Society a paper* on the use of the Launhardt Formula in railroad bridge design, and showed the error of its derivation and the impracticability of its application. At the same time he suggested the advisability of appointing a Committee for the general revision of bridge specifications. That formula has now practically disappeared from use, and railroad bridge specifications have been gradually moulded into standard form. Mr. Seaman.

It was with somewhat the same purpose in view that the present paper was prepared. The specifications presented therein embody many features which have become almost standard, and, with these as a basis, suggestions have been made for further advancement, in order that the work may be made more comprehensive and complete.

There is no reason why a general specification should not apply to spans of any length. The principles of mechanics are universally applicable, and there is no fixed line of demarcation, either in theory or in practice, between long- and short-span bridges. The properties of materials are now well understood, and shop practice is so thoroughly organized that there is no economy in doing second-class work.

The principal features necessary for such a broad application is the proper selection of a unit strain, to which all conditions could be equated, and the establishment of a formula for the purpose of equating these various conditions. The unit strain selected is that for which the static loads may be safely applied, and the formula is for the purpose of reducing all live-load strains to a static equivalent.

The formula proposed is empirical, and is the curve of a quarter ellipse. There appears to be no reason why a conic section should be especially applicable to these conditions, but the results obtained are fairly satisfactory, and nothing else has yet been proposed which meets better the tests which have been made. This is noted on the diagram, Plate XII,† presented by Mr. Bowen. Our theories upon the subject are so varied and hypothetical that confirmation must depend on practical conformity with tests.

Many formulas have been already proposed, and Mr. Cochrane has shown a number of these on the diagram, Fig. 19.† It may be noticed, on that diagram, that the ellipse is generally lower than the other

* *Transactions*, Am. Soc. C. E., Vol. XLI, p. 140.

† *Proceedings*, Am. Soc. C. E., for February, 1912.

Mr. Seaman. formulas, but Plate XII shows it above the tests, and considerably above the latest formula proposed for the American Railway Engineering Association, that is, $I = \dfrac{100}{1 + \dfrac{l^2}{100}}$. The curve for that formula passes through the tests, and would naturally require a greater factor of safety, by the use of a smaller allowable unit strain, than would be necessary for the higher elliptical curve shown.

Objection has been made that our formula for static equivalent gives more than 100% increase for very short spans. If we were considering merely the impact from a rolling load, this criticism would be well founded, but that is only a small part of the increase. Unbalanced drivers and flat wheels, which cause the sharpest blows, are particularly effective on short spans. Tests on track have shown that this force exceeds 200%, at times. The subject of static equivalent is too broad to permit of hurried discussion; we will undoubtedly hear more of it in the future.

Together with the formula for static equivalent, must be considered the allowable unit strain on the material, as the two subjects are interwoven and inseparable. In the preparation of these specifications, the allowable unit strain was carefully considered. At first the formula, $S = 100 - \sqrt{20\ L - \dfrac{L^2}{100}}$, was adopted for static equivlent, and an allowable strain of 16 000 lb. per sq. in. was used to correspond. This, however, was not satisfactory, as it was not applicable to long spans; and even for short spans—constructed with modern shop workmanship—it seemed unnecessarily wasteful. It was then suggested that to increase both the formula and the allowable unit strain by 25% would produce practically the same bridge, except that there would be greater provision for counterstrain, and a slight saving in the dead-load section. The dead-load sections, however, are all increased when we provide for full live load over the entire span, which load actually seldom occurs. For an unloaded bridge, therefore, there is always surplus section.

In the specifications, two grades of steel have been provided: medium carbon and nickel steel. These may be used indiscriminately, the latter generally in long spans, and wherever the saving in weight offsets the higher cost of the material.

The question has been raised—and very naturally—as to the propriety of using an impact formula in the design of highway bridges. It must be remembered that this is not an impact formula, but rather a formula for static equivalent. To the writer's mind there is no impact on highway bridges, and very little, if any, on railroad bridges. It was for this reason that the term, "impact," was avoided. The

Mr. Seaman.

increase in strain on railroad bridges is due principally to other causes than impact from the sudden application of rolling load, and, similarly, the increase of strain in highway bridges is due to the tendency to congestion rather than to impact. This tendency to congestion, or local intensity, increases with shorter spans, and the gradual variation from long spans may be represented by a formula; yet this need not necessarily be the same as that selected for railroad bridges. On the other hand, if, on investigation, the same formula would seem to apply, there is no objection to its use, and one formula, instead of two, simplifies the specification.

The known facts as to highway bridge loading are so variable and indefinite that extreme refinement is unnecessary, or impossible, and it is again found that the conic section will give results quite as satisfactory as any other formula that has been suggested. The only change which the writer has felt inclined to make is the possible reduction of the initial load from 80 to 60 lb. per sq. ft.

The excellent discussion by Mr. French must be carefully read to be fully appreciated. The writer has embodied several of his suggestions, in the specification.

The claim that reinforced concrete beams and slabs, when made continuous over supports, should receive credit for continuity, is well taken. This has already been permitted by the writer in his practice, and in the specifications under "Bending," in reinforced concrete, it would seem advisable to change the fourth clause so as to read as follows:

"4th.—Partial continuity may be assumed in the design of beams and slabs, and the moment, $M = \frac{W\,L}{10}$ may be used in place of $\frac{W\,L}{8}$, where the conditions warrant it. In any case, however, steel reinforcement should be provided over the supports to prevent cracking."

In regard to timber structures, which have been mentioned, it has long been recognized that the heavy modern loading was endangering the short trestle spans. The 15-ft. span has practically been abandoned in favor of 12 ft. 6 in., and three heavy stringers are now commonly used where two light ones were formerly sufficient. Twenty-five years ago the writer designed trestle stringers at 1 000 lb. per sq. in. on the outer fiber. If that rule were still in use, trestles which have now two stringers at 1 400 lb. strain, would require three stringers of the same size. It should be remembered that unbalanced drivers at high speed will give heavy blows. The quality of timber to-day is no better than that of former years.

Mr. Seaman.

Mr. Gardiner offers some very interesting data in regard to emergency stops. In some instances this would seem to justify the old provision of 20% for sliding friction in bridge design, but when it is realized that this is only momentary, and that a large portion is taken up by the rail connections and floor system, it appears that only part of the thrust reaches the main structure.

The suggestion that, either the writer's working strains are too high, or that the specifications formerly in use lead to wasteful designs, expresses exactly what the writer has wished to emphasize. The specifications in general use—except for very short spans—do lead to wasteful designs. Bridges designed for heavier loading, with correspondingly greater allowable strains, will have a much better distribution of material. The difficulty with the Quebec Bridge was not that the loads were too light, as the load was never applied. The cause of the disaster was insufficient latticing in unprecedentedly large compression members.

The clause of the specification which permits the flanges of beams, when embedded in concrete, to receive 25% increase of strain, makes allowance for the fact that the concrete will relieve such flanges of a portion of the strain.

Although an allowable strain of 20 000 lb. per sq. in. is permitted on steel in concrete, for uniformity; as a matter of fact, it will never receive such a strain. The suggestion to use 0.7% to 1.5% of steel, limits the strain to less than 16 000 lb. per sq. in., by reason of the comparative elasticity assumed for steel and concrete.

The author has adopted a number of the excellent suggestions made by those who have taken part in the discussion, and hereby expresses his thanks, as the spirit of discussion, in every case, shows a disposition to share the responsibility which we are mutually carrying.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

HOW TO BUILD A STONE JETTY ON A SAND BOTTOM IN THE OPEN SEA.

Discussion.*

By Mr. L. J. Le Conte.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The writer's experience has not been in accord with the author's general conclusions. Jetties are usually built in pairs, converging slightly from the gorge toward the original crest of the bar. At this point convergence ceases, and they run practically parallel, and about 1 000 ft. apart, heading for the shortest distance to deep water—say, 40 ft. at low water. This is given as 40 ft. because that is the depth now demanded in all the main seaports. Mr. Le Conte.

For reasons given later, the writer prefers the old-fashioned way of building out from the shore first, until the crest of the bar is slightly overlapped. He would then spread out an apron of rip-rap some 600 ft. beyond the bare end of each jetty, and stop. A long series of observations would follow, in order to ascertain the facts about local conditions. The first thing is to dredge a jetty channel from the gorge out to a depth of, say, 40 ft., and then watch the annual amount of shoaling, which is the only true measure of the necessity of extending the jetties into deep water. This is a most serious consideration, involving great expense. It is always followed by doubtful results, and, therefore, should not be undertaken before making the most painstaking investigations. If the annual amount of shoaling in the channel outside of the bar is not very great, then this extension is entirely uncalled for, simply because annual dredging is now being done so cheaply and expeditiously that it does not pay to extend jetties.

A little investigation will clear up this conclusion. Theoretically, of course, both jetties should be extended out to a depth of 40 ft. in

* Continued from February, 1912, *Proceedings*.

Mr. Le Conte. order to make and maintain a 40-ft. navigable channel without dredging. A conservative estimate of the distance from the crest of the old bar out to such a depth is 3 000 ft., more or less. The cost of extending both jetties from the bar for this distance will probably be \$3 000 000, the annual interest on which, at 4%, would be \$120 000, which would easily pay the running expenses of a first-class bar dredge for the entire year. Such a dredge would be able to work half the time and would take out fully 600 000 cu. yd. per annum, which is greatly in excess of any shoaling that is likely to take place in 3 000 ft. of channel. In all probability, the annual shoaling would not exceed 100 000 cu. yd. This could easily be removed from the channel for \$15 000, which would be the annual charges instead of \$120 000, the interest account.

Furthermore, the foregoing assumption is not strictly true, that is, that the extension of both jetties to a 40-ft. depth would probably do away with dredging entirely. Experience almost everywhere seems to show that, in nine cases out of ten, in course of time a new bar will form across the 40-ft. entrance; so that probably some dredging will have to be done in addition to the heavy interest charges of \$120 000 per year.

A practical study of the existing facts in jetty construction will invariably end in omitting any proposed extension into deep water, because, from a purely financial point of view, there is absolutely nothing in it.

The writer, however, agrees with the author about many things, namely, framing the specifications so as to make use of the entire output of the quarry, because this has to be paid for in any case, and why not make use of it; also, his remarks about the hearting wall and big stone facing on the slopes, and maintaining the apron out in advance of progress work. The superstructure from the low-water plane up to the crest of the jetty can now be built, with much better satisfaction, of monolithic concrete reinforced at and near the outer ends.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE JUST VALUE OF MONOPOLIES, AND THE REGULATION OF THE PRICES OF THEIR PRODUCTS.

Discussion.*

By Mr. Maurice G. Parsons.

Mr. Parsons.

Maurice G. Parsons, Jun. Am. Soc. C. E. (by letter).—This paper is timely, although it follows closely the papers entitled "The Going Value of Water-Works"† and "The Valuation of Public Service Corporation Property."‡ The questions discussed are of present political and business importance, but the principles used in handling them are neither entirely established nor very widely spread. Academic economists throw but little light on their practical solution, leaving the engineer largely to his own resources, therefore a wide discussion of monopolies and prices, by engineers, and from many viewpoints, is highly desirable.

There is to-day "a sound of a going in the tops of the mulberry trees," new to this generation. We are emerging from the factory system and entering the trust age—the age of more complete division of labor, of combination, of artificial and natural monopoly. Competition in certain branches of business seems to be dead, to have yielded to natural monopoly. Without going into the question of whether we will soon have monopoly in all activities, it may be stated with confidence that natural monopoly is here to stay for some time. Competition, with its wasteful duplication of plant and management, has been found uselessly expensive. Competition, with its combinations—conspiracies against the public—has been found more apparent than real.

* Continued from March, 1912, *Proceedings*.

† *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 326.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 1.

Mr. Parsons. The natural monopoly is the inevitable and welcome method of supplying many present-day needs.

When the people realized that monopolies were not only being benefited by the advantages obtained by the elimination of competition, but were also artificially raising prices, various remedies for this unjustness began to be suggested. Taxation of net income, taxation of gross income, rate regulation, and Government ownership are a few of the many schemes having for their object a fair adjustment between cost of production, prices, and income. All aim—some directly, some indirectly—at rates.

The author has discussed the most fundamental part of the problem, which is also the most difficult phase to solve, namely, the determination of a fair rate of profit. Much thought has been expended, but, in the writer's opinion, without reaching a satisfactory solution.

First, it would seem that Mr. Mayer has failed to grasp the fundamental difference between competitive concerns and natural monopolies. Generally, more risk is involved in competition, due to ability or trickery on the part of other concerns, than in natural monopoly. A monopoly risks only the welfare and patronage of the people; a competitive concern risks also the dangers of competition. Competitive industries must have duplicate plant and management, thereby entailing, in general, expenses greater than those of a monopoly doing the same amount of business. A monopoly is often the creature of the people, originating in an exclusive franchise. For those reasons may not one ask whether a profit or a price fair under competition is necessarily fair under monopoly?

The second trouble with the author's solution may be defined as one composed of a mixture of doubtful reasoning and difficulty of application. Of what avail will it be in any individual case to know average prices and profits if "the profits of individual monopolized enterprises must remain vastly different to secure economy of production"? Will it not be as difficult "to ascertain the just differences between the prices of the same product in different places" as it will be, without a knowledge of average prices, simply to determine just prices? A question might be raised as to whether it is right to assume that competitive profits are fair rather than exorbitant or low, since many competitive concerns have grown unduly wealthy and others have failed. It might be fully as hard to decide whether competitive profits were fair as it would be to determine, in any given case, a fair monopoly profit. Certainly competition—when, indeed, there is real competition—is influenced by monopoly in fixing prices. Again, what would one do, under this method, were he asked to fix a monopoly price for an article not produced by competitive establishments? The Interstate Commerce Commission has had difficulties in its endeavor to enforce fair competition, but the labors of this body would be small

compared to those of commissions detailed to determine average profits for all kinds of local, State, and National organizations. Even after this average profit has been determined the engineer must deviate therefrom in any given case. Mr. Parsons.

A third question arises after a study of this paper, namely, the author's method of evaluations. If a monopoly is valued by its stock, one must, to be just, squeeze out the water. To waive the privilege of a physical valuation, as affecting prices, but to establish the amount of fair securities, after knowing what a fair price will bring in, seems rather like a merry-go-round to those who hold that, in a measure, fair prices are determined by some kind of evaluation. Of course, we no longer hold to the labor theory of value, but we can admit the plant as a factor in value: To pay a man for time given, whether to a necessary or a useless object, is one thing; to hold that a natural monopoly, supplying a public necessity necessarily only with the aid of a large investment, is entitled to rates influenced in some degree by the relative amount of capital tied up, is another. Evaluating a business by capitalizing its profits is looking at things from the investor's point of view rather than as one who seeks to establish a fair rate.

To the writer, a rational method of dealing with the entire problem is that outlined below. This has fair rates, and its object is the gradual lowering of these rates, to be obtained indirectly rather than directly. We cannot arbitrarily say that 50-cent gas is just—perhaps it is and perhaps it is not. The subject must be approached by a roundabout path.

The first step is the determination of a fair percentage of profit on the investment. Money sunk must be protected. Money sunk in a risky venture is entitled to more reward than that invested in a sure proposition. Money put in necessary enlargements does not deserve as high a return as the original capital used in developing the business. Pioneer monopolies, treading unknown ground, should be more highly rewarded than those following a beaten path. The just percentage of net income—the fair profit—may differ with each case, but can it not be as well established arbitrarily as by any other method? This is a hard question to settle, the one of fair profit, but it is fundamental. Why not weigh the risk and say that 5, 10, or 20% is fair to a natural monopoly, rather than become involved in average competitive profits?

The consumer is directly concerned with two things: Prices, which are frequently an object of criticism; and adequacy of service, which generally escapes notice unless it deteriorates. Certain it is that natural monopolies should be regulated so as to secure for the public an adequate and economical service. The word adequate is meant to be used in a literal sense, thereby excluding luxury of service. A simple illustration will suffice: Water companies should furnish ample water without uselessly expensive, uneconomical works. At the same

Mr. Parsons. time, it is wrong to saddle a community with rates to pay for a plant of ten times the required capacity. We must have just enough and just the right kind of service, economically furnished.

The third factor in fixing a just rate, the actual cost of production, is one involving an array of engineering problems. None of these can be solved, except by rough guess, unless thorough and accurate accounting and physical record systems are kept. The development and physical value costs are two of these problems. Depreciation and sinking fund expenses can be but approximate. "Who can tell what a day will bring forth?" Still there are cases when these factors have been supposedly worked out to a cent. Operating expenses are more easily ascertainable, even though the economic expenditures in this direction are extremely complex in some cases. The cost of production, as determined by all its factors, should be a just one. It is not right to recoup too rapidly for development outlays, nor should the next generation pay the depreciation charges of to-day. In a growing community the natural monopoly should be regulated so as to secure proper extensions. These should come when they are needed and should be economically secured.

Guided by these factors—fair profit, adequate service, cost of production, extensions—the fixing of rates becomes a simple matter. We approach the question of rates indirectly. We should enforce administration policies to secure not the lowest possible rate of the moment, but the long-time, economical, low rate.

Where will all this regulation end? Perhaps, finally, it will go no further than regulation. Perhaps we shall have Government ownership of all natural monopolies. Perhaps we shall have Government ownership of all business. Business and government are, in the last analysis, on the same foundation; both exist for, and by virtue of, the people. If the Government does take over all business, we have to go still deeper and see who runs the Government—whether it be the people or the money—but with this the Engineer is not professionally concerned. He has, however, a duty as a citizen at the polls. If the people want anything long enough and sincerely enough, they can get it. The Engineer's duty at the polls, however, is a minor one; his big duty of citizenship is at the tiller of business. What is needed is not men with their ears to the ground, nor men who endeavor to stave off this or that public or private opinion. Absolute justice is, at best, difficult to obtain. We, therefore, need engineers who will play fair; who will keep faith with both sides; who will steer a straight course; who will exercise good business sense; and who will solve our problems.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROBLEM OF THE LOWER WEST SIDE MANHATTAN WATER-FRONT OF THE PORT OF NEW YORK.

Discussion.*

By Messrs. T. Kennard Thomson, Calvin Tomkins, Ernest C. Moore, Reginald Pelham Bolton, Henry B. Seaman, J. H. Gandolfo, E. De V. Tompkins, and A. W. Robinson.

Mr. Thomson.

T. Kennard Thomson, M. Am. Soc. C. E.—Mr. Cresson and Commissioner Tomkins deserve great credit for the way in which they have presented this subject, and for the great amount of honest hard work that they have done toward solving the very serious, in fact, the vital, problem of handling freight in New York City; for, it must be patent to everybody that something must be done at once if New York is to maintain the position it should. If it is impossible to supply the demand for docks now, the condition must become worse every day, even before the opening of the Panama Canal, the Barge Canal, and the Intercoastal Canal, for any of which New York is utterly unprepared. Europe, South America, Boston, Philadelphia, are awake and spending millions, while New York sleeps.

For the past 15 years the speaker has never lost an opportunity to point out that Manhattan is no place for a terminal of any kind—either freight or passenger—and on February 6th, 1898, he published† a plan to solve the Brooklyn Bridge terminal problem by simply abolishing the Terminal and continuing the line to West Street, thence northward, turning to cross the Williamsburgh Bridge, making a wide circuit in Brooklyn and then connecting the Brooklyn end of the old bridge. (Fig. 2.)

* Continued from March, 1912, *Proceedings*.

† In *The Brooklyn Eagle*.

Mr. Thomson.

If this had been done, with practically an endless chain of cars running in both directions, connection could have been made at once with all north and south lines in Manhattan and passengers could have been transferred readily from the Bridge loop to the line desired without being forced to get off the bridge cars at points inconvenient for nearly all. The subsequent Bridge loop, which has been built but not yet put in operation, will not accomplish the desired result, as most of the passengers will still have to leave the train before reaching their destination and then take a long walk. The speaker's object in citing this is simply to give an example, known to all New York, of a very bad situation in the passenger terminal line, and if it is so hard to handle passengers in a terminal, will it not be much harder to handle freight?

Mr. Cresson has shown the congestion of freight all along the water-front, and trucks waiting their turn to reach the docks. Even allowing for systematic handling, will not the congestion on the streets become worse when, instead of distribution at every dock, the bulk of the freight is bunched into a few terminals, as he suggests?

Another objection to Mr. Cresson's plan is the fact that freight from Philadelphia to Lower Manhattan must go many miles out of the direct route; this is unnecessary, as will be shown later.

Still another objection is that the number of tracks which would be required would make this roundabout route impossible on account of the cost. It would be interesting to have a railroad man work up a train schedule showing how the requisite quantity of freight could be handled, and stating the number of tracks required.

A vice-president of one of the big trunk lines has stated that, if the speaker's plan of freight belt lines of tracks around Manhattan and Staten Island is carried out, at least eight or ten tracks will be kept busy. A belt line could certainly handle much more than a dead end with terminals. Mr. Cresson's plan does nothing for the East Side, unless by trucking across the city.

The speaker would respectfully suggest to Mr. Tomkins that, to make the Dock Department's plan feasible, he put his tunnel near the Battery and run an 8-track freight road around the entire Island of Manhattan, having the tracks on the street level inside of the dock line (off the street), if possible, with an elevated street above the tracks (as has been suggested by Mr. McBean), and tunnels under the tracks at each ferry for automobiles and trucks, the passengers crossing overhead. By this plan, freight cars could be readily unloaded at any point of the water-front, thus affording distribution instead of concentration.

Mr. Cresson has cited the Pennsylvania Railroad Tunnel to show that his scheme is feasible, but nobody denies that tunnels can be built under the North River; however, from all reports, the Penn-

Mr. Thomson.

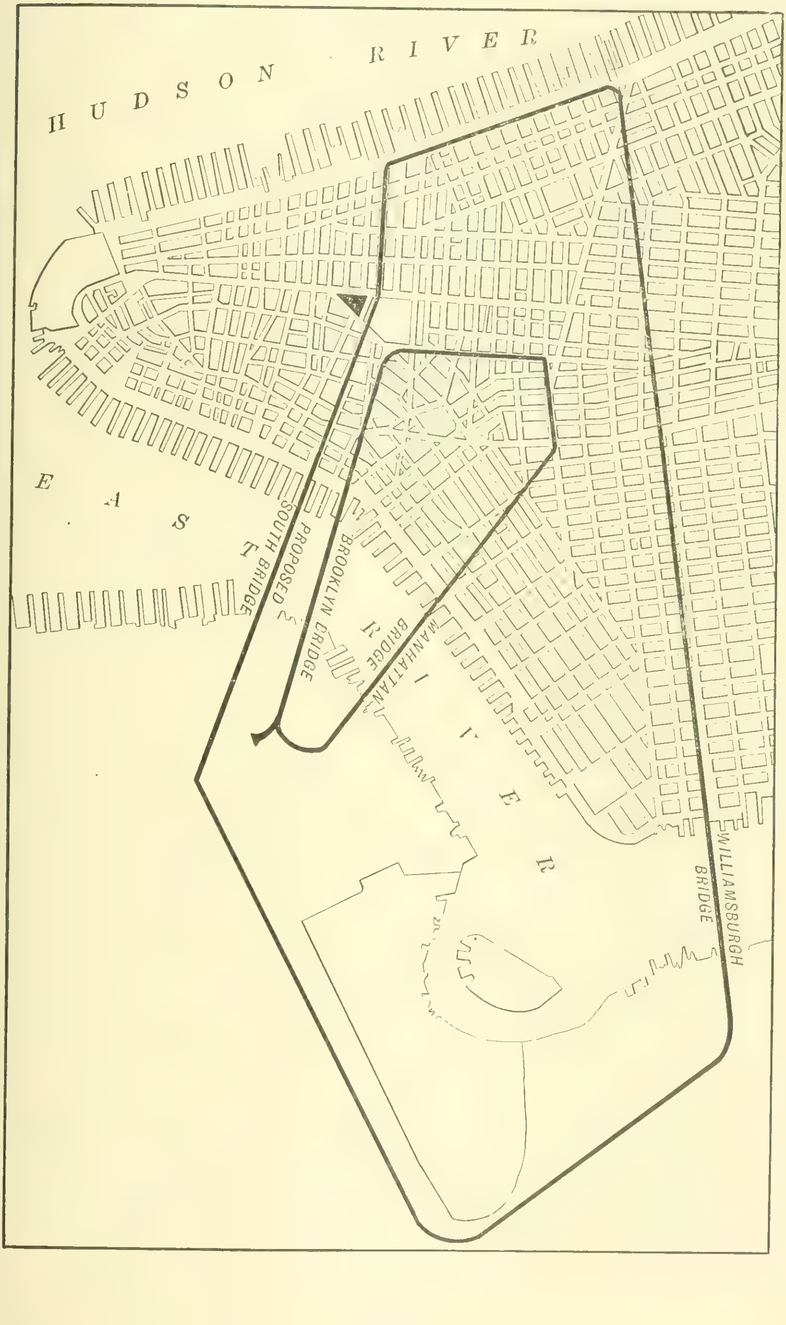


Fig. 2. The Inner Circuit Shows an Inadequate Belt Line; the Outer One an Adequate Belt Line.

Mr. Thomson. sylvania Tunnel is not a financial success, and, if used as a criterion for building a freight terminal, the shippers and other victims would probably object to the great burden of expense.

In April, 1911, the speaker submitted to Mayor Gaynor a plan which would afford immediate relief in many ways. This plan, Fig. 3, consisted of:

1st. Extending the Battery 4 miles into the Bay by building a new city, 10 blocks wide and 80 blocks long, or 800 square blocks; thus adding to Manhattan 1 400 acres and more than 8 miles of new docks, including dry docks, sites for public buildings, etc.

2d. Connecting Staten Island to Manhattan by an 8-track tunnel, $1\frac{1}{4}$ miles long, thus giving the Pennsylvania, Baltimore and Ohio, and other railroads the most direct entrance to Manhattan.

3d. Connecting South Brooklyn with the Manhattan extension by another tunnel.

4th. Constructing freight tracks around Manhattan (6 tracks at least) and around Staten Island (4 tracks to start with), and also freight tracks around the Brooklyn shore, with the great benefit of an arrangement which would permit a full-sized freight car to be taken promptly, and by the shortest route, to any dock in New York and at once unloaded without having made any unnecessary 20 miles of detour.

Thus, without being asked for a cent of money, the City could obtain 8 miles of new sea walls for docks, and increase the taxable value of Staten Island from \$50 000 000 to \$500 000 000 and also levy taxes on at least \$1 500 000 000 worth of new property; or, in short, collect more than \$50 000 000 of new taxes every year.

It has been claimed that these great improvements might depreciate the values of land on Manhattan; but how could any plan which involved the expenditure of at least \$50 000 000 every year in this locality help but improve every foot of New York City and State?

It would take a Jules Verne to imagine all the benefits that would accrue, among the lesser of which would be abolishing car-floats, preventing interfering currents at the Battery, saving 2 hours' time for ocean steamers, putting the City Hall in the center of New York instead of at the end; and, in fact, everything connected with the building of a model "City Beautiful."

It might be stated here that, after sending this plan to Mayor Gaynor, Mr. Cresson showed the speaker the plan, published by Mr. H. Arnold Ruge some years before, for joining Governor's Island with the Battery of which the speaker had not heard prior to writing the Mayor.

Mr. Thomson.

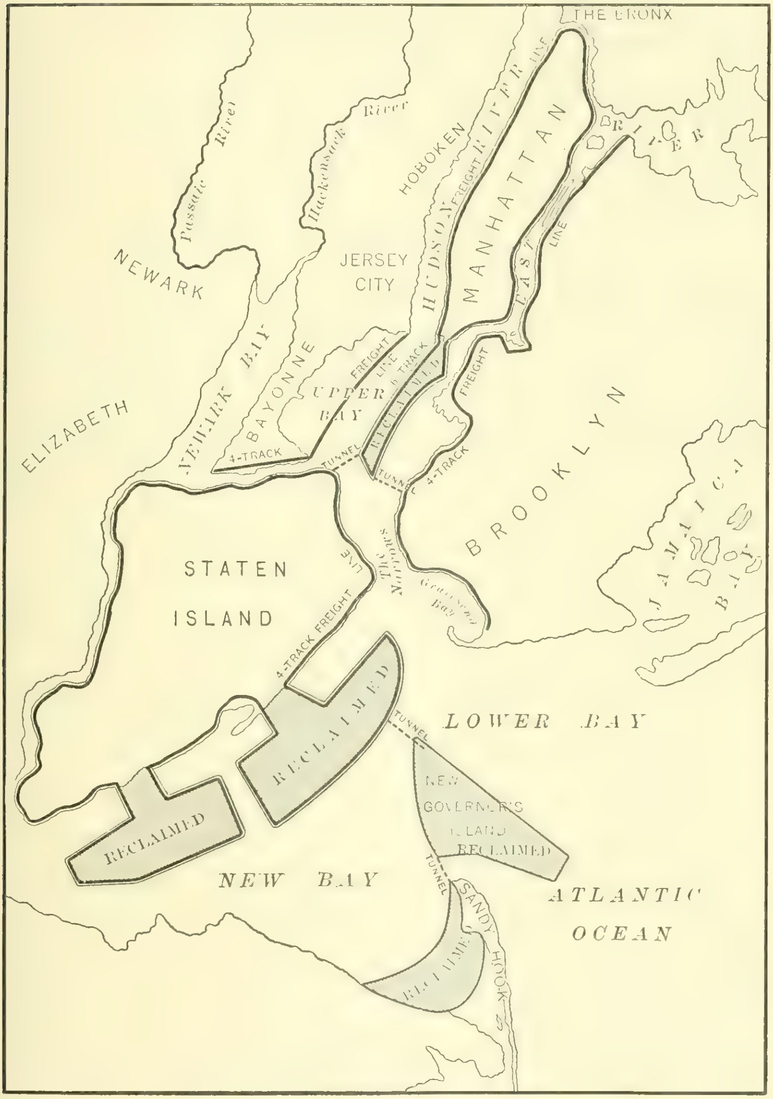


FIG. 3.—A SOLUTION OF THE NEW YORK HARBOR PROBLEM.

Mr. Thomson. The speaker's first idea was simply to connect Governor's Island to the Battery, but he discarded it as useless when the idea occurred to him, weeks later, of continuing the extension for 4 miles until Staten Island could be reached by a reasonable tunnel.

Nobody wants to build or ride in a 5-mile tunnel from Staten Island, but a tunnel $1\frac{1}{4}$ or $1\frac{1}{2}$ miles long would be satisfactory. In short, permission to extend Manhattan could not be obtained unless the resulting benefits to the whole city were great. The speaker believes that, when these benefits are fully realized, the City and State of New York will never rest until they are obtained.

Where rock can be reached, the speaker would simply build a coffer-dam and pump it out, instead of back-filling; then the building of subways, sewers, pipes, etc., would be simplicity itself.

After the speaker had formulated this plan, he realized that within 5 years after its completion this Manhattan extension would be entirely inadequate to take care of the growth of the city, the population of which will probably double (from 6 000 000 to 12 000 000) during the next 30 years, if not restricted; so he developed the second part of this plan, though he did not deem it advisable to do more than refer to the latter.* This second part has never been shown to any one outside of the speaker's office (except two men), and is now brought before this Society. It is shown on Fig. 3, and the principal features are:

1st. Build an island (New Governor's Island) near Sandy Hook, to contain about 8 sq. miles, in such a way as to form a new bay, much larger than New York Bay.

2d. Reclaim many acres on the inside of Sandy Hook.

3d. Reclaim two strips of land and connect them with Staten Island in such a way as to form the maximum amount of fine harbors for docks, etc., making in all about 30 sq. miles of valuable property for shipping, manufacturing, and other purposes; and

4th. Connect all these lands with tunnels.

The Government could then give up the Brooklyn Navy Yard for a much better one; give up Governor's Island for a much finer site; and the City would be able to take care of the traffic of the Barge Canal, the Panama Canal, the proposed Intercoastal Canal, and any other sudden increase in shipping, instead of being continually obliged to refuse requests for docks and thus force the shipping to anchor in the bay for days at a time, which, of course, is very expensive.

The Lower Bay proposition should not be carried out before the Upper Bay portion, but work could be started on it as soon as the latter is completed.

* *Engineering News*, May 11th, 1911.

Of course, the scheme for deepening the East River, proposed by W. M. Black, M. Am. Soc. C. E., should be carried out, but the City should not waste money which it cannot afford on the many other schemes submitted, involving many millions of public money, as their usefulness is very debatable when a project like this can be handled by private enterprise. This plan would afford quick relief and yet be capable of further developement for 50 years to come, 100 years being too far ahead for the speaker's vision. Mr. Thomson.

Calvin Tomkins, Assoc. Am. Soc. C. E.—The speaker will consider this subject from its larger viewpoint, and not from the technical side. Under the direction of Mr. Cresson, and with the assistance of Messrs. Staniford, Hoag, Betts, and other engineers of the Dock Department, to whom great credit is due, the details of this plan have been carefully worked out. Mr. Tomkins.

The port problem of New York is not local. The Dock Department is regarded by the people of the City, and largely by the officials, as a kind of fifth wheel in the Municipal Administration; it is considered as important, but about it they know very little. It is removed from the immediate touch of their daily existence, and they do not appreciate the magnitude or difficulty of the problem. They do not realize that the cheap handling of commodities in and out of the Port, on both sides of the Hudson River, is the factor on which rests the continuous, orderly, progressive development of the City. It is a national problem. It is in effect an international problem; but it is so mixed up with local affairs which, in the eyes of the citizens, are of more immediate importance, that it does not receive the attention it should.

On the completion of the Panama and Erie Canals—and the possible termination of the freight discrimination against the City of New York—the Port's new responsibilities cannot be measured by those of the past. Mr. Hoag has said that nobody, even a few years ago, could foresee the size of modern ships; but, after all, it is the growth of the City which is most responsible for the pressure on it; and we are confronted with the problem of managing the commerce of the greatest port in the world.

New York, at present, is second in size only to London, and is first in importance as a seaport. In former times, Venice, Amsterdam, and London, each in turn, became the world's great ports for international exchange. Commerce was diffused between English and North Sea ports during the last century, and there was no one great world's seaport such as New York will be on the completion of the Panama Canal. This is the responsibility which confronts the City, and for which, during the last three years, it has done little to prepare itself. It has

Mr. Tomkins. maintained existing docks in a good state of repair, but has done almost nothing in the way of new construction.

In former administrations, the responsibility was recognized to some extent, and it is not fair to state that the City has not had a very comprehensive port policy, as far as it could see ahead. In 1871, New York, in advance of all American seaports, began to municipalize its water-front. It has made the most of its water highway along the East and North Rivers, and, until Messrs. Jacobs, Davies, Forgie, and their associates demonstrated the practicability of passenger tunnels under the Hudson River, there was nothing to depend on but the water highway and transmission by car-floats over that highway. With the advent of tunnels, however, this water-highway idea may be considered somewhat in the nature of a traffic tradition, as it is not the most economical method of transporting freight around the harbor, though undoubtedly, the car-float will be used for outlying Boroughs and minor terminals after tunnels have been built. Before the advent of freight tunnels, dependence was placed on car-floats altogether. That direct, continuous, all-rail connections are the cheapest, is shown: by the efforts of the New York Central Railroad to come down from Spuyten Duyvil to 60th Street and thence to Lower Manhattan; by the construction of the Pennsylvania passenger tunnel from New Jersey across Manhattan to Long Island; by the construction of the Pennsylvania Bridge across Long Island Sound; and by the prospect of a tunnel to complete the route under or near the Narrows. The tendency is away from intermittent car-float transmission and toward continuous tunnel or bridge transmission.

The port problem, stated very simply, is the proper co-ordination of railway terminals, and is not at all novel. Briefly stated, it is to put each part of the harbor to its best natural uses, and plan with the expectation of subsequently connecting all the parts through the instrumentality of tunnels and floats; that is all there is to it. Fundamentally, it is a question of co-ordinating and bringing together the various railroads about the port.

In Bremen, Antwerp, and Manchester, there are systems of loop lines of railroad connections, making every part of the port available to every other part, so that the cars from any railroad have access to all parts, with no expensive transfer charges to factories or warehouses.

It must be remembered that New York, in addition to being the greatest commercial city in the world, is also the greatest manufacturing city in North America, and its prosperity depends on its industries more than on its commerce. Commodities passing through the city, or going into warehouse or terminal and being brought out again, are of little local importance in comparison with the raw materials which are brought here to be wrought into finished products

Mr. Tomkins.

and sent out to the markets of the world, thus increasing the revenues of the City. It is of more importance that every factory in the City should have a railroad siding connecting it with the ocean terminals of the Port and with every railroad, so that it can find ingress and egress for its raw materials and products.

The problem is not so much a steamship as a railroad problem. It is not novel, as has just been stated. The City is not making any radical departure, but is simply following the well-trodden path of experience along which the great ports of the North Sea have advanced, except that local conditions are being adjusted under the guidance of that experience, and such changes are being made in local plans as local conditions make necessary. The ultimate idea is that of joining all parts of the Port, including the elevated railroad on West Street, with tunnels to New Jersey and Long Island, and utilizing the New Jersey meadows for distribution and classification yards.

One of the difficulties in the organization has been the magnitude of the Port itself; such an embarrassment of opportunities does not exist anywhere else in the world. The difficulties of the present time will be most beneficent influences in the future, when they have been conquered and harnessed to our needs.

The Port is divided into four grand sections by the harbor waters: New Jersey on the west, Long Island on the east, Manhattan and the Bronx at the center, and Staten Island on the south. It is difficult to connect these parts by tunnels. It is impossible to do so at once; it must be done gradually, keeping a policy in mind and following it up.

The jurisdiction of the Port lies in two States, which, at the present time, is a difficulty; but the appointment by the Governors of these States of two Commissions, which are associated, is a long step toward solving these interstate complications. In the long run, the speaker is convinced that the interstate character of the Port will be an advantage and not a disadvantage, because there must be interstate regulation by the Federal Government over the terminals at the Port, before there can be unity of administration and unity of control over rates and terminal charges, to make the Port most effective.

The greatest difficulty is the tradition among the railroads of utilizing terminals for competitive purposes. Competition among the railroads, since the advent of the Interstate Commerce Commission, has been confined to that at terminals. This is all that is left of the drastic competition of former days. The railroads have established extensive terminals to attract freight to their lines. In competition with each other, they have been obliged to do this. The richer and more enterprising lines have secured the best terminals, and they are naturally loath to give up their advantages to other railroads.

The organization of this Port, like those of Antwerp, Hamburg, or

Mr. Tomkins. Manchester, involves the abandonment of this individualistic advantage, and means that freight collected at any part of the Port, or sent over any railroad to the Port, should enjoy the use of all the terminals. The poorest and the least enterprising railroads, would thus have about the same advantages as the richer and more enterprising ones, and that, naturally, is not acceptable to the latter. Not only at New York, but at Baltimore, Philadelphia, and Boston, the effort is being made to co-ordinate the railroad systems and substitute for expensive transfer charges a cheap switching charge. At present almost all the endeavors of Baltimore and Boston are being directed toward this end, rather than toward the creation of a great physical system of docks, which is not needed. It is peculiarily difficult to do this in New York, because there are so many railroads, with such intense rivalry between them; but, under the force of public opinion and business necessities, this is coming.

The City was given power by the last Legislature to administer the Port and create terminals in a most comprehensive manner. The law has clothed the Dock Department, under the Board of Estimate and Apportionment, with perhaps dangerously large powers in this respect—not only to take the water-front and make terminal improvements on it, but to take the lands back of it and organize them; to build railroads and warehouses, and, if necessary, to operate them; and even to take lands, impose a plan upon them, and sell them or lease them after the plan shall have been imposed. That bill gives the City the power of excess condemnation in the Dock Department, which no other city enjoys. The speaker believes that, if it can be shown that the plan is a public necessity, the Courts will sustain the law.

There is also power under the law to create or permit the creation of private terminals, as distinguished from railroad or manufacturing corporations—a new kind of corporation having certain limited powers —so that advantage can be taken of private capital and private experience as well as those of the municipality.

The speaker's idea of an improvement policy is that the City should plan the physical construction, make the land acquisitions, and then create terminal corporations and turn over the administration to them—either to railroad or terminal corporations—taking advantage of private capital, ability, and experience, rather than saddle the City with all these responsibilities at this time. The City should now adopt a large and comprehensive plan for future development.

Mr. Cresson has called attention to the principal factor in that plan, the West Side terminal extension; but the Dock Department has plans for South Brooklyn, which involve a larger extension and are bound to come soon; plans for Staten Island, the Bronx, and the East River; for Newtown Creek, which Mr. Forgie mentions but does not enlarge on; and for all the various parts of the Harbor.

Next to the Panama Canal, the organization of the Port of New York is probably the greatest physical undertaking that the world has before it at the present time. This is not an exaggerated statement, and the speaker does not believe that the Dock Department has solved the problem finally; but it has made an attempt to do so; it has, at least, taken the responsibility for the attempt. The plan is there, for what it is worth, subject to such criticism and modification as may be found necessary. The speaker wants the best plan that the City can get; and, in relation to the West Street plan, hopes it will be criticized. Certainly, there are none more competent to do that than the members of this Society. Mr. Tomkins.

The West Street plan is the key to the whole situation. Until that is settled, the Dock Department cannot tell what to do with the big ships; whether they are to come to Manhattan (where they want to come with their passengers and freight, for the same reasons that the railroads want to come), or whether it will be necessary to send them to South Brooklyn, if they must be excluded from Manhattan in order to provide for the railroads. The City's policy should be made known quickly.

The railroad traffic on the West Side of Manhattan must be taken care of first. That is a fact which has come home to the speaker with greater force since he has been Dock Commissioner, than it did before. The impression has grown that the railroads can be removed or restricted in their operations at the water-side and steamships put in their place. This cannot be done until equally good or better facilities are provided for them on the land side of the street.

The railroads bring the food supplies to Manhattan, and take away the package freight, and they must be permitted to remain at the dock front until better provision is made. This is the way to solve the problem—the only way, the speaker believes—and if this plan is not adopted at once, it will be later, because there is no other way.

The reason is that it is impossible to cut the tracks of the New York Central Railroad. It would be like cutting the throat of the City of New York, commercially speaking, for this railroad has the only direct, continuous, all-rail line into the city. There are many lines coming from the West to New Jersey, but there is only one line coming to New York City. The City cannot cut the tracks, in conformity with the suggestion made by a majority committee report of the Board of Estimate and Apportionment, and close the traffic. The Dock Department wants to discontinue floating from 60th Street that large portion of the products which comes over the Central lines now. It wants an up-to-date all-rail route into Lower Manhattan, instead of the slow and expensive transit over surface tracks. A large part of the New York Central's freight comes by car-floats from the 60th Street yard; and if the road is cut at 30th Street or 60th Street, there

Mr. Tomkins. will ensue a still greater movement of car-floats and a still greater congestion at the dock front of Lower Manhattan. Therefore, it is a question of getting the tracks off the surface of the streets, and more conveniently located. Provision must be made for a more continuous movement. The Courts have recognized the franchise rights of the New York Central Railroad; and they say it cannot be kept out of Manhattan; but the method which that road shall use to bring its freight down can be imposed by the City, if its conditions are reasonable. That is what the Dock Department is endeavoring to provide—reasonable conditions for taking care of that traffic—thus relieving the congestion on the water-front and on West Street. As Mr. Forgie has stated, the present method is not civilized; we are past that stage.

It can be done in either of two ways: through the instrumentality of an elevated railroad, or by a subway, and the speaker has no predilection for either. The engineers of the Dock Department have examined into the matter very carefully, and have come to the same conclusion as Mr. Forgie—that a subway is impracticable on account of its cost of construction and operation, and its danger. It cannot be brought below 30th Street. Its construction would create a great disorganization of traffic; it would be dangerous to operate; and the set-offs which are so easily obtained by the elevated railroad could not be obtained by the subway without great expense, risk, and danger.

The last choice is a marginal elevated freight way. Shall it be a New York Central enterprise, or shall it be available for the other roads as well? The very best and cheapest facilities must be provided for this road; interference with its traffic must not be permitted, because it is expected that it will act as the pace-maker and the rate-maker for the other railroads. By creating the very best conditions under which it may operate, there will be created the conditions under which the other railroads must also operate. If this road comes down over this elevated railroad, and the others are prevented from using it, that road will dominate the freight situation of the West Side of Manhattan absolutely. The other roads would not be willing to submit to this. Already their unfriendly attitude has changed, since the Department has shown a way of enabling them to use it by tunnels, under as favorable conditions as the New York Central will enjoy.

When the railroad is built and the Central uses it, the other roads must use it. It is not intended to compel them to use it. As Mr. Harding has said, when the railroad managers find a cheaper and better way of doing their business they will do it that way; and if the opportunity is held open to them to use the elevated freight facilities they will take advantage of them. The erection of this elevated railroad, and holding the opportunity open to the other railroads, means the eventual abandonment of the dock front by the railroads, and the opening of the docks to the uses of steamships, for the railroads will

have indefinite room for expansion on the land side of West Street. The whole situation will thus clear up in Manhattan. This cannot be done at a blow, but must be a gradual, orderly procedure. Mr. Tomkins.

The one criticism of the City Government, from the Dock Department standpoint, if there is any criticism to be made, is that it has not acted promptly in this matter. Public interest has been so absorbed in subway and police matters, and in sundry measures of very great local importance (though the speaker does not wish to minimize their importance in any sense whatever), that this matter has not been given sufficient attention, and the consequence is that action has been delayed. The New York Central, under the latest legislation, was obliged to submit its plans on October 1st, 1911. It complied with the law. At the speaker's request, its plans were then referred to the Dock Department, and he took them up with the engineers, and one month thereafter the Department submitted plans. Physically, these are very much like those of the New York Central, but differ from them in providing that the elevated road shall be a public highway below 60th Street, giving the Central such rights as it requires, and reserving running rights for the other railroads.

As the Central officials will undoubtedly stand out for the best terms they can get from the City, and the City will try to get the best bargain it can, an immediate conclusion cannot be expected. The speaker does not think that any legislation will be necessary to compel the Central to accept a reasonable plan. He believes this plan to be a reasonable one, and that in all good faith the differences that may be found between the City and the Central can be adjusted through negotiation rather than through legislation; but the City has lost much time since November 2d, 1911, in refraining from negotiation.

As Mr. Cresson has said, the Dock Department is not seeking to bring business to Manhattan; in fact, the whole purpose of its plans is to create terminals sufficiently attractive in outlying boroughs, so that manufacturers will go away from Manhattan. We are seeking to modernize the New York Central terminals in Manhattan, and make more room for transatlantic and coastwise steamships and their passenger business.

The speaker would like to reiterate: If there are any criticisms of these plans, to be made by any members of this Society, he would like to have them as soon as possible.

Ernest C. Moore, Esq.—The freight-handling problem of the West Side of New York City has received constant attention for the past twenty years. Many of the leading engineers of the United States have been called in consultation, and many committees from the leading business organizations of the City have been appointed at various times for its consideration, and though many reports and recommendations have been made, nothing has yet been accomplished. Mr. Moore.

Mr. Moore. The urgency for the settlement of the question has increased as time has passed, until now it has become absolutely necessary that an early conclusion be reached. Some of the most urgent matters are:

First.—The necessity for the removal of the freight tracks of the New York Central Railroad from the surface of Eleventh Avenue.

Second.—The necessity of providing terminals for the Barge Canal along the North River.

Third.—The organization of the freight-handling business of the railroads on the North River. At present freight is handled from car-floats over the piers and by trucks through the streets. The railroad facilities for doing this work are now taxed to the utmost, and business is still increasing.

Fourth.—The necessity of providing additional facilities for the steamship business. Many applications are on file in the Dock Commissioner's Office for additional pier space for steamers; and this business must either go to some other place or have additional facilities provided here.

With these facts in view, the Board of Estimate, in July, 1910, authorized the appointment of a committee of engineers to pass on the engineering features of the situation. The speaker had the honor of being one of the members of that Committee.

In considering this problem, the Committee had before it the various plans and recommendations which had previously been made by other committees and engineers who had studied the situation. In order to get all the facts with regard to present conditions, the Committee first called a meeting at which the attendance was requested of an officer of each of the various railroads serving the city. At this meeting one vice-president of each railroad was present; a great deal of confidential information was asked and obtained as to the quantity of freight handled, the cost of handling, the amount of increase in the past ten years, etc.

It was the desire of the speaker and the other members of the Committee that a unanimous report be rendered and that the Committee be able to recommend a plan which would be acceptable to all parties and be adopted.

It was finally concluded that one of three plans must be adopted: A subway; an elevated railroad along West Street; or the construction of separate terminal stations on the east side of West Street to be connected with the piers by a bridge over the street and a ramp down to the pier level.

The Committee agreed that the problem involved was that of getting the railroad freight business into terminal stations on the east side of West Street and relieving the water-front as much as possible of railroad occupancy.

Mr. Moore.

It was further agreed that joint terminal stations were desirable from the standpoint of the City's interest, and it was also thought that this plan would be to the interest of the railroads. With this point, however, the railroad officials disagreed, because, owing to the workings of the Interstate Commerce Commission, competition between railroads in handling freight has been largely reduced to promptness of delivery and competition in the terminals. This competition might disappear in a joint terminal, or favoritism might be shown. There are a number of joint terminals in successful and satisfactory operation, both to the shippers and the railroads, however, and it seemed to the Committee to be only a question of management.

As to the best method of bringing about these results, the Committee unfortunately could not agree. With regard to the subway it was agreed that it would be impracticable below 30th Street, but two members of the Committee recommended the construction of a subway down to 30th Street with the so-called unit terminals below that point. The speaker could not join in the recommendation as to the subway, because it appeared to him that it would cost at least three times as much as an elevated railroad; that it would not serve the shippers so well; that it would be difficult of access; that it could not be connected with the piers; that as it would be very expensive to connect with buildings, its utility would be much less; and that it would give permanent possession of Eleventh Avenue to the New York Central Railroad and forever block the reorganization of the freight business above 30th Street.

With regard to the unit terminal stations, their adoption did not seem possible. A large number of the railroads terminating in New Jersey are seriously in need of additional facilities on the east side of the river, and the privilege of building these terminal stations was offered to each railroad with the assurance that, if acceptable, the Committee would unanimously recommend their construction to the Board. Even under these conditions, and after a very considerable time had elapsed, neither the New Jersey railroads nor the New York Central Railroad would agree to undertake any such construction, even if they had the privilege. The reason is not hard to understand.

The construction of one of these unit-terminal stations involves an investment of about $10 000 000. It would require almost as much space as two piers, and, with the possible exception of one or two places on the North River, could not be constructed without destroying at least two piers, so that a railroad company, in undertaking this construction, must lose the use of two of its piers for at least one year and perhaps two, and it must make an investment of about $10 000 000 without the least assurance that the new equipment would increase, even to the very slightest extent, its handling capacity over that enjoyed before the reconstruction of its piers. This is hardly a

Mr. Moore. proposition which any railroad could be expected to accept. Furthermore, if such an installation was built, it must necessarily be for the use of a single railroad and would not be a joint terminal, as the piers at which these constructions would have to be made are now controlled by the railroads, and no railroad would accept joint occupancy with another railroad on its own property. The limited space between the station and the pier is an insurmountable obstacle to the successful operation of this plan, and in view of the fact that, in the available space, a railroad operation over the numerous sharp angle switches and steep grades involved in the plan proposed cannot be carried on without great difficulty and expense, the capacity of such a station must be very much restricted.

Looking at the matter from another viewpoint, and assuming that the switching layout will supply the station to its full capacity, it seems fair to compare it with that of other stations in actual operation. The capacity of St. John's Park Station, of the New York Central Railroad, is 350 000 tons of freight per annum, and this station is worked 24 hours per day. It is true that its capacity might be considerably increased by mechanical devices, but, after all, the capacity of a station is determined by the area of its loading platforms and the length available for teams.

A comparison of those items is as follows: The area of the team platforms in St. John's Park Terminal is more than double those of the Unit Float Terminals. In the former the team frontage is somewhat greater than that in the latter. St. John's Park has about 50% more team tracks than the proposed Unit Terminals, and the area of one floor alone is nearly 50% greater than the two floors in the proposed Unit Terminal combined.

If, therefore, there is assumed for the Unit Float Terminal a capacity of 350 000 tons per annum, it should seemingly be a liberal allowance. The capacity estimated by the Committee for such Unit Float Terminal is 1 500 000 tons, or from four to five times greater than what would seem probable. This estimate makes no provision for future expansions, being for the full capacity of the stations proper and the actual present tonnage.

The handling of the present traffic of 5 000 000 tons by the various railroads in Lower Manhattan, as stated by the Committee, therefore, would require fifteen such terminals; or, as the unit terminals occupy more frontage than the average city pier, a space equivalent to approximately 5 775 lin. ft. of water-front, or the equivalent of approximately twenty-five city piers. The number of terminals required for the district below 30th Street, as estimated by the Committee, is nine, occupying one pier for each terminal, or a total of nine piers such as are now used by the railroads. At the Barclay Street Station, the New York Central has two piers, and the amount of freight handled

over these piers is almost exactly the same as that handled at St. John's Park. Mr. Moore.

Considered from the standpoint of the City, the proposed plan meant a permanent easement to the Railroad Company, forever blocking any harbor improvement or modified use of the docks which future conditions might require. It would require the construction of a number of transverse elevated structures across West Street, thereby cutting off permanently its use for the construction of a longitudinal elevated railroad, either for passengers or freight; and as there could be no assurance of any increase in the capacity of these structures, the City would have no assurance of any relief whatever from pier congestion on the North River, which is one of the principal objects of a re-organization of the freight-handling situation.

Another matter of vital importance adverse to the unit terminals is the fact that the river bottom between Christopher and 46th Streets is of such a nature that piers constructed in it are continually settling. This would be fatal to the operation of cars and electric locomotives over the intricate system of switches which would be necessary on the piers.

On the other hand, it seems that the elevated railroad, which is the plan proposed by Commissioner Tomkins, would meet every one of these requirements. The Jersey railroads could be connected directly with the elevated railroad by tunnels under the North River, and their pier occupancy could be very largely, if not entirely, done away with. Switches from the elevated railroad could reach the piers on one side of the street and the warehouses on the other, and if this plan was recommended to the Board and adopted by it, the New York Central Railroad stood ready to build the structure at once, either for its own use or, through agreement with the City, for the use of all roads; and this it seems must be the construction which will be carried out eventually in the solution of this question.

Mr. Forgie seems to think that New York is not much of a manufacturing city, but is more of a financial city. The following figures from the Census Report of 1905 will tend to disprove this:

"New York is not only the greatest commercial city of the country, but it is also the greatest industrial city. According to the census of 1905, there were in this City 20 839 manufacturing establishments, nearly one-tenth of the entire number in the United States; these had a capital of $1 042 946 487, constituting over 8 per cent. of the total industrial capital of the United States; they employed 464 716 wage-earners, who, with their families, constituted over 50 per cent. of the City's population; there is paid in wages $248 128 259 a year to these workmen, a sum equal to the entire internal revenue receipts of the United States. The total value of manufacturing products in New York City in 1905 was $1 526 523 006, a sum almost exactly equal to the total foreign commerce of the port of New York in 1909, and

Mr. Moore. amounting to 10.27 per cent. of the total value of manufactured products in the United States.

"There are more manufacturing establishments, more manufacturing capital, and more value of manufacturing products in New York City than in any State in the Union, except the State of Pennsylvania, and, of course, the State of New York, of which this City is a part."

The records of the Building Department show that permits are issued annually for the construction of 1 000 new factory buildings in the Borough of Manhattan alone.

Mr. Bolton. REGINALD PELHAM BOLTON, M. AM. SOC. C. E. (by letter).—Mr. Cresson's paper is a very clear and interesting re-statement of the arguments which for some time past have been advanced by Calvin Tomkins, Assoc. Am. Soc. C. E., Commissioner of Docks. These arguments, while they very properly and clearly describe the existing deficiencies and inconvenience, do not, in the judgment of those equally entitled to express opinions on the subject, offer solutions which would have the effect of immediate and future relief, without permanent injury to the future interests of New York City.

The proposals made by Mr. Cresson, as well as by the Commissioner of Docks, seem to be based on a limited conception of the possibilities of other means of relief, and mainly on preconceived assumptions that the trade and traffic of the West Side must be handled in a manner similar to that of such institutions as the Bush Terminal, or of other ports where the conditions are totally different from those now obtaining, or in the future to obtain, on the West Side of New York City.

The ordinary port terminal, such as in Montreal, New Orleans, etc., is a place of wharfage for vessels to which direct railroad communication is very properly provided, but the dockage of ships along the margin of the Island of Manhattan is not of the same class of wharfage, and the business handled is not of the same character.

It is evident that the West Side of Manhattan is destined to accommodate large passenger steamship traffic, the freight of which is mainly of the package description, and that the relation of railroad-borne freight to this traffic can best be provided by water carriers. The purpose of a connecting freight railroad is not evident from the conditions, either as laid down in this paper, or as disclosed from examination of the actual situation.

It is difficult to find any fundamental value in the proposition of a marginal railway, more especially in the form proposed, of an elevated structure to which cars have to be hauled by switching and grading from car-floats, or raised by excessive grades from long under-river tunnels, as proposed in the Dock Commissioner's scheme.

The confusion likely to arise by cross traffic, from the numerous points of entry of the cars, can readily be conceived, and also the condition to which the West Side would be reduced by the drilling

into position of a large number of cars for passage to and from one or other of the assumed terminals. What saving would there be, for instance, in hauling a freight car from the vast yard in Brooklyn, proposed by the Dock Commissioner, down under the East River, up again to Manhattan along the west front, to some point to be transferred into the terminal to which it could have been much more readily brought by a car-float directly from its original position. Mr. Bolton.

The whole scheme of a marginal railroad back of the docks is evidently unsuited to the West Side conditions, where the object of the handling of freight is its transfer to or from the street truck.

A far better scheme is that proposed by W. J. Wilgus, M. Am. Soc. C. E., for a freight tunnel of small section, and of similar character to the Chicago freight tunnels, extending not only along the West Side, where its application and value would be restricted, but into the interior of Manhattan.

The scheme of a marginal elevated railroad is destructive of the hopes and necessities of the public in the matter of passenger transit along the important lines of access which West Street affords, and the interests of the Port will be far better served by a passenger railway, transferring passengers, baggage, and express freight, than by any scheme for handling the cars of railroad companies.

The immediate difficulties with which the Dock Department finds itself confronted can best be met by a prompt provision of suitable equipment for the more rapid handling of freight in and out of cars on car-floats. The necessary terminal facilities, which Mr. Cresson proposed should be provided on private property on the east side of West Street and the marginal way, can be provided just as well, and to much better purpose, on city property, on the piers themselves, where the present use of this valuable space is of the most limited and restricted character.

In place of using twenty-nine piers along the West Side by railroads, it is evident that proper interchangeable terminal facilities could be provided, as proposed by the Special Committee of the Board of Estimate and Apportionment, at nine selected points along the west front, and if provided with buildings covering the piers and containing a number of floors, and with modern facilities for lifting and transferring, not only the freight but the cars themselves, and teams and trucks to and from such floors, there can be no question that the railroads' freight business would be handled effectively and cheaply, greatly to the advantage of the City, and largely to the financial advantage of the railroads, by a reduction in the number of leases involved by their present methods.

Such a development is suggested in Fig. 4, in which a five-story building, on a dock 700 ft. by 100 ft., affords space for locating and loading or unloading 150 cars, with ample room for teams and trucks

Mr. Bolton. on intermediate floors, all goods being disposed of by chutes extending from the platforms of one floor to those of another.

The cars would be lifted from the car-floats by exterior elevators, and transfer tables would align the cars on the respective floors. Trucks would be elevated to the proper floors, and descend at the opposite end of the building.

Such a use of water-front property eliminates the disadvantageous features of crossing the marginal way and West Street, either at grade or overhead, and concentrates the handling of goods at the points of major movement, creating in a vertical direction the additional amount of space required by the growth of traffic, a process which has been followed in every other business except that under consideration.

The propositions, advanced by Mr. Cresson and the Dock Commissioner, for dealing with the second and immediately pressing problem of the provision of longer piers for the great vessels soon expected in this Port, are equally lacking in purview, and seem to be rather helplessly confined to a single method of solution of the difficulty. This solution takes the form of a proposition to destroy at short notice an institution of long standing, namely, the West Washington Market, thus introducing a complete change in a business of considerable importance, and effecting radical alteration of certain methods of business, all for the purpose of securing a single site on which the Dock Commissioner appears to have set his mind as the only possible position for a long dock in the immediate future. The plan also involves a radical re-arrangement of the important West Side marginal street.

The situation which now confronts the City in this matter is a logical result of the stupid and grasping methods by which the invaluable water-front has been allowed to be filled in to such a point that proper space no longer exists for the length of piers which are now, and will in the future be, required; but it will be evident that, if the planning of the future arrangements of the West Side water-front are seriously taken in hand, a more practical and permanent solution can be found than the proposition of the Dock Commissioner, to tear out the market and construct one or two long piers which, at the most, would afford only a temporary relief.

The proper course to be taken is evidently the reconstruction of some considerable portion of the water-front improvements in the form of piers at an angle with the present position, by which piers up to a length of 1 200 or even 1 500 ft. could be provided at several points along the water-front.

Had this course been taken in connection with the West Chelsea dock improvement, the present difficulty would not have arisen. It is an open question whether the handling of these great vessels could not

Mr. Bolton.

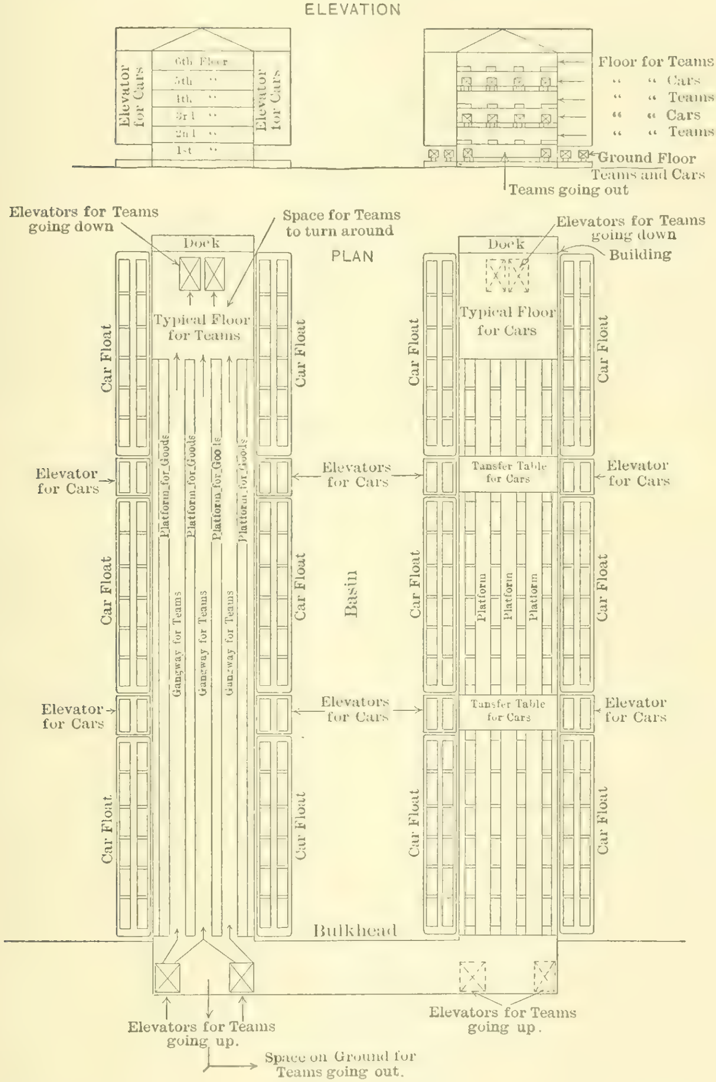


FIG. 4.

Mr. Bolton.

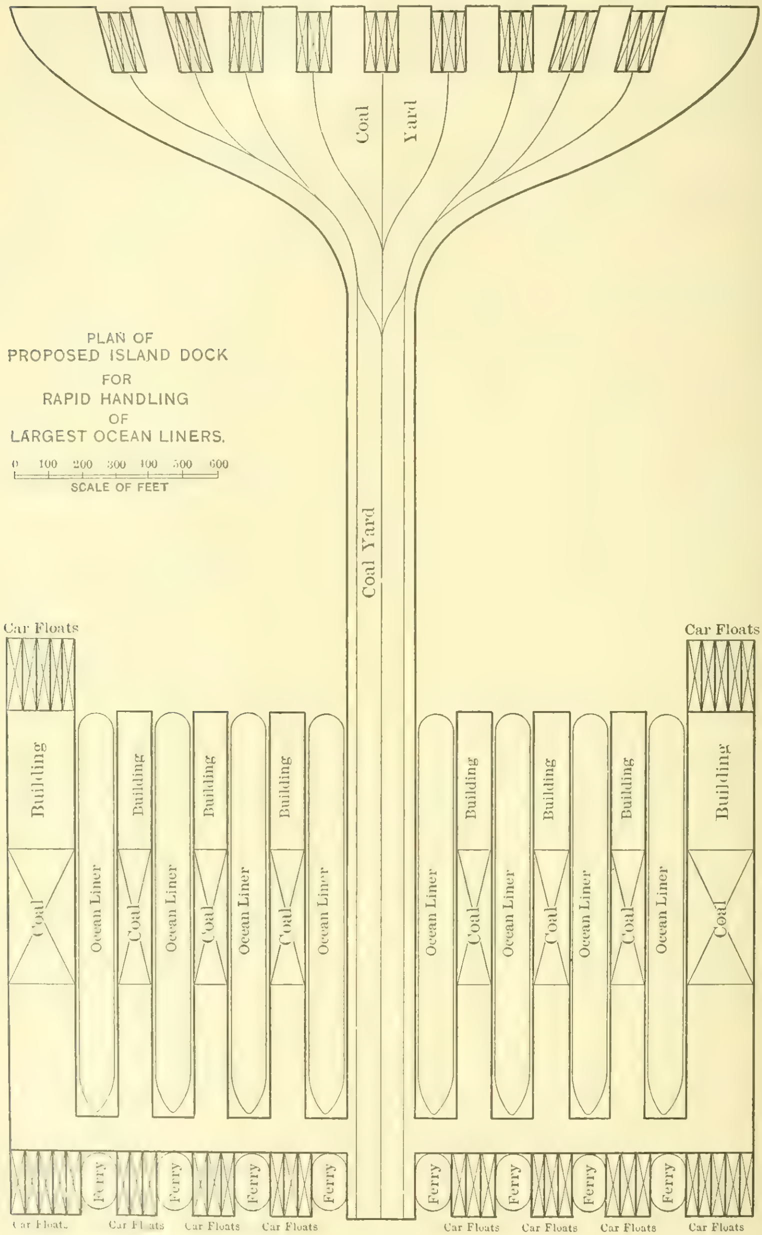
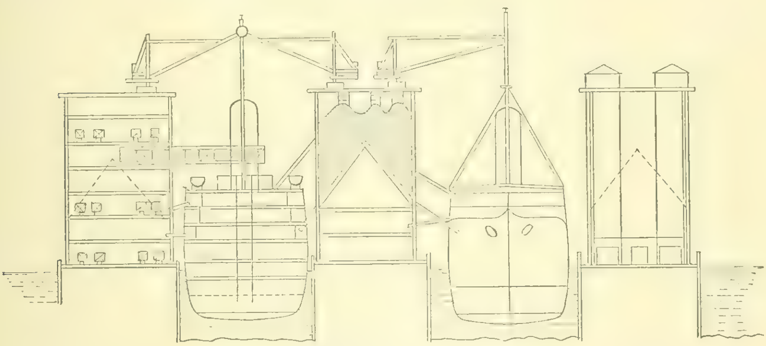


FIG. 5.

be accomplished better by the provision of a landing stage for passengers, baggage, and express matter, and the reloading and coaling of such vessels at an island dock near Liberty and Ellis Islands, in which these processes could be conducted at a higher rate of speed than is possible with the present dock system, or alongside the street. Mr. Bolton.

It seems strange that vessels, the charter value of which runs from three hundred to many thousands of dollars per diem, should be served so ineffectively under present conditions as to require their presence at a dock for days at a time. Under future conditions, one would expect to see such vessels unloaded, reloaded, coaled, provisioned, and dispatched within not more than 24 hours after their arrival, whereby a much greater use could be made of the investments, both of the vessels and the docking and other facilities provided.

A suggestion for such rapid and intensive operations is outlined in Figs. 5 and 6, a plan and section of a loading and coaling dock provided with means for the transfer of goods directly from and to railroad cars in buildings on both sides.



ELEVATION OF
PROPOSED ISLAND DOCK
FOR
RAPID HANDLING OF LARGEST OCEAN LINERS.

Fig. 6.

Finally, this consideration of the subject leads to the enquiry why the present pier system should remain spaced according to the street spacing, whereby vessels are handled only from one side at a time. It would appear to be desirable that a great deal more study and thought be devoted to this whole subject by the Department of Docks, before attempting to carry into effect measures for a solution of the difficulties which have grown up around the imperfect methods of the past.

It is to be hoped that before any of the remedies proposed by the Dock Commissioner are fastened upon the City, very thorough consideration will be given to methods and means of relief, some of which have been briefly outlined herein.

Mr. Seaman.

HENRY B. SEAMAN, M. AM. SOC. C. E. (by letter).—Mr. Cresson's paper is a very complete presentation of what has been termed the "West Side Problem" of Manhattan. He naturally views the subject from the standpoint of the water-front, which shows, perhaps, its most important commercial aspect. Another consideration, however, is almost as important, namely, the elimination of the steam railroad on the street surface of Eleventh Avenue, and, also, the reduction of the cost of cartage through the streets of the city.

Several years ago, in behalf of the Public Service Commission of the City of New York, the writer took up the question of city cartage, and the results then reached were not very different from those now presented by Mr. Cresson.

The West Side problem is, indeed, one of the most important which the City faces to-day. Rapid transit subways, from a purely engineering standpoint, are practically solved. Their present difficulty seems to be a financial, and, it might be said, a political or personal, rather than a scientific one, but the West Side problem, while including difficulties with vested interests, is, in the main, a question for broad and intricate engineering investigation.

The phase of the subject which the writer had under consideration was the decrease of the cartage congestion through the streets of Lower Manhattan, and, at the same time, as already mentioned, the elimination of the railroad tracks on Eleventh Avenue.

The amount of cartage through the streets is proportional to the distance hauled, that is, if the distances were reduced one-half, the cartage (except for delays at the terminals) would be decreased proportionately. Furthermore, in order to decrease the congestion and the delays at terminals, the latter must be more widely scattered about the city, rather than concentrated in one locality.

In order to decrease the cartage, goods in bulk should be delivered as near their point of destination as possible; and, to accomplish this, there should be a series of terminals around the belt of the district served. As Lower Manhattan is about 2 miles wide, these terminals might be about 2 miles apart—closer in districts of congested business, and farther apart where business is more sparsely distributed. These distances would probably vary from 1 mile to 4 miles, depending on local conditions. By this arrangement, not only would the haul through the streets be shortened, but, at the same time, the terminal work would be distributed and extreme congestion avoided at these points. The cost of local cartage would be reduced, because of less delays at terminals and shorter hauls, and local expenses would be more nearly comparable with those of other ports.

If this method of distribution were adopted, the next consideration would be how to reach these terminals. A belt line is the natural means; but should it be on the water which surrounds the island, or should it be by elevated railroad?

The waterway has been generally recognized as the cheapest and most elastic means of transportation, particularly as most of the railroads are on the New Jersey shore of the North River. It is a route which has been afforded by Nature, and, in the early days of New York City, before traffic had grown to its present proportions, it was the only practicable means of delivery. Mr. Seaman.

The use of the waterway necessitates either that the terminal be on the river side of the marginal way, or that tracks be laid across the street at grade, because it does not seem practicable to elevate the cars to an overhead crossing within the short distance from the river. The introduction of more grade crossings would not be tolerated, and the river-side terminals now in use, although a natural development, have grown until they have reached such proportions as to cause the present congestion and demand early correction.

It is due to this condition of local distribution that the proposition of an elevated railroad is presented. The harbor has been established so long on its present lines that a complete development of railroad connections, with piers, warehouses, and local terminals, must be one of gradual change, or evolution. The railroad is already needed to relieve congestion at certain points, and also for the purpose of eliminating the railroad on Eleventh Avenue. If trans-atlantic vessels continue to increase in size, as they probably will, the oblique pier in the North River will be a necessity, and this, in turn, will facilitate railroad connections.

By the process of elimination, the writer concludes that the elevated railroad is the ultimate solution, but the City should look far enough ahead to avoid temporary expedients. The proposition to construct float-bridges is decidedly of a temporary character. Their use would be cumbersome and restrictive. A tunnel under the North River, with complete railroad connections in New Jersey, would be an essential of the development which the writer believes would be most wise to construct at the outset.

J. H. Gandolfo, Assoc. M. Am. Soc. C. E. (by letter).—The problem of handling the steadily growing freight traffic in and about New York City, and of providing adequate docking facilities for the ever-increasing steamship business in this port, should receive careful study, and nothing on a large scale should be done, either by the municipality or by private interests, until the problem has been considered from every point of view and the rights of all concerned so correlated as to work no injustice to any one company or individual. Mr. Gandolfo.

It is to be regretted that Mr. Cresson did not go into more detail, and give estimates on which arguments could be based. For example, it would be interesting to know the cost of such a terminal railway as he proposes, what returns the City could expect for such an outlay, and whether the income would be sufficient to make it a

Mr. Gandolfo. paying investment and not throw an additional burden of taxation on the people.

Mr. Cresson speaks of "permanent overhead rights" to be acquired by a railroad. It is very doubtful if any such rights can be granted "in perpetuity" by any legislative body, as it is contrary to the fundamental principles of law that any legislature can limit or restrict the powers of any succeeding legislature. In this the writer uses the term "law" as referring to primary principles, not to "law" as interpreted or administered by present-day jurists.

In regard to a municipal elevated railroad, and its control by the City, it is regrettable to have to state that, in New York City, at least, municipal control is a failure. In support of this statement the writer calls attention to the following five cases, taken at random from the City Departments:

(*a*) The present wretched condition of the street pavements throughout the city.

(*b*) The absolute failure of the Street Cleaning Department to keep the streets in anything like a cleanly condition.

(*c*) The complete failure on the part of the Police Department to give that protection to the law-abiding community which the citizens have a right to expect and demand.

(*d*) The fact that the water supply system of a great city like New York is laid out, constructed, and controlled, so that the breaking of a single pipe in some sections of the city deprives entire districts of water for hours at a time, and exposes them to all the dangers of a conflagration.

(*e*) The statement by the Park Department itself that certain parks are in such a condition that the lawns must be entirely made over, and that large sums of money must be spent for this work, although this Department was supposed to be taking care of the parks; and the statement of this same Department that the way to take care of the trees and grass plats along a certain avenue is to do away with them entirely and asphalt these areas.

All these examples are in departments under complete and absolute municipal control, and these conditions continue to exist in spite of the fact that large sums of money are appropriated annually for the maintenance and extension of their work.

One often hears the expression, "crowded New York." Certain districts are very much crowded, but it is a fact that there are large areas, close to congested districts, of which very little use is made, and this is the case along lower West Street. With a few exceptions, such as the old and new Whitehall Buildings, 90 West Street, the Central Building, and, farther up-town, a few factories and

warehouses (and those who are familiar with this section know how very few these are), the east side of this street is occupied by old and dilapidated buildings only three and four stories high, and, in many cases, of only one and two stories. These buildings are occupied for the most part as beer saloons, small shops catering to sailors and 'longshoremen, horse-shoeing establishments, and things of a similar unimportant nature. Buildings of the same class occupy not only the blocks extending between West and Washington Streets, but also a large percentage of the blocks extending to Greenwich Street, the next street parallel to the river. Thus, there is an area of a full city block, and often of two city blocks, extending back from the river along West Street, of which very little use is made. In regard to relieving the congestion along this thoroughfare, the writer wishes to present the following schemes in outline. The ideas here set forth have to do with the handling and storage of freight and the relief of the congestion along the docks and bulkheads. No attempt is made to go into the matter of providing longer piers, as the writer has not yet made a detailed study of this part of the problem. In discussing this matter, the subject will be divided into two parts: Mr. Gandolfo.

(*A*) Handling freight to and from steamships.

(*B*) Handling freight to and from railroad cars.

(*A*)—*Handling Freight to and from Steamships.*—Many of the docks along West Street are of primitive construction, consisting of only a shed roof to protect the contents of the pier from the weather. These docks should be replaced gradually by modern two-story structures, and equipped with modern appliances for handling freight. The steamship companies should acquire the property along the east side of West Street and opposite their piers; or, it might be advisable for the City to obtain control of the property opposite such piers as it owns, and lease it with the piers, thus, although controlling the property, permitting its management and use by private interests, and deriving a revenue therefrom. On this property, large warehouses should be erected, and equipped with all modern appliances. The first floors of such buildings should be devoted to platforms for loading and unloading trucks; thus, if an entire block was secured, giving four sides for the arrival and departure of trucks, and as many interior driveways for loading and unloading as a detailed study would show to be advisable. From these platforms, vertical conveyors and platform elevators should extend to the floors above.

The second floors of these buildings should be designed so as to act as a feeding space for the shore ends of conveyors, which should be carried across West Street on light bridges, and extended out on the docks at the level of the second floor. A conveyor of a trolley type,

Mr. Gandolfo. with overhead track and individual carriages, a continuous belt conveyor, or a moving platform, can now be built so as to handle a great variety of miscellaneous freight. The writer has studied conditions on many piers, and finds that in a majority of cases, nearly all the freight on a pier can be handled with such a system. The very small percentage which could not be handled in this way, could be taken care of on the first floor of the pier, as is done at present. On first thought, one objection to this scheme might be that all goods must be elevated to the second-floor level; but, as a large part of the freight is kept in warehouses, it would simply be a question of bringing it down to the second floor, instead of the first. Further, in loading a large vessel, the freight is now raised to a high level by booms on the dock or the ship and dropped into the hold, and it would be just as easy to sling this freight from the second-floor level and lower it into the hold; and *vice versa,* in unloading vessels. The conveyors for such a system should be reversible, so as to work equally well in either direction.

(B)—Handling Freight to and from Railroad Cars.—The various railroads should acquire the property along the east side of West Street, and opposite the piers controlled by them, or such property should be controlled by the City, as previously stated. Loading slips for car-floats should be provided at the river ends of such piers. An incline, on which the cars could be handled by a cable and bogie truck, should extend from near this end of the pier to the second-floor level. The tracks would then be carried along the pier at this higher level, and across West Street on bridges. Two, three, or even four, tracks could thus be provided along the dock. On the east side of West Street, warehouses similar to those described under (A) should be built, except that the second floors should have loading and unloading platforms to accommodate freight cars. As the tracks come from the docks, they should expand, and by ladder tracks, or any other arrangement of switches and curves, reach the tracks through the warehouses. By a proper layout of these tracks, it would be possible to use the blocks adjacent to those directly opposite the pierheads, and also extend the tracks across Washington Street and use the blocks between Washington and Greenwich Streets. It is probably needless to say that movement on such a railroad should be by electric locomotives.

As already stated, the warehouses for the railroads should be similar to those for the steamship companies, the first floors being used for handling freight to and from trucks, and the floors above the second for the storage of general merchandise. By a proper arrangement of elevators and conveyors, the handling of freight within the warehouse could be reduced to a minimum.

Mr. Gandolfo.

The advantages of such arrangements are as follows:

(1) Each steamship line or railroad would control the movement and handling of its own freight, and would not be interfered with in any way by any other interests.

(2) It would relieve the congestion along West Street, as there would be four street façades to every block, where trucks could arrive and depart.

(3) It would entirely relieve the piers and bulkheads from the handling of car freight.

(4) It would obviate the necessity of car-floats standing in the slips all day. As soon as a float was unloaded, it could be loaded again with cars ready to be transferred to the sorting yards in New Jersey.

(5) The first floors of piers thus used for car tracks could be given up to such lighter merchandise as would not warrant the expense of installing such a system of conveyors as described under (*A*).

(6) It would reduce to a minimum expensive hand-trucking; holding trucks idle while waiting their turn at the string piece; early closing day, on account of breaking up the rafts of floats; and many floats standing idle while others are being loaded.

(7) West Street is from 200 to 250 ft. wide along the greater part of its length below 23d Street, part of this space now being used for sheds for the temporary storage of merchandise. The congestion along this street having been relieved by these means, and there being no longer the necessity for this storage space, the slips along this water-front could be lengthened inland from 50 to 100 ft., and still leave ample street space.

As Mr. Cresson states, any scheme of this kind is capable of almost indefinite alteration or extension. For example, the conveyors to the steamship piers, in some cases, might be carried under West Street in subways, provided too much trouble would not be caused by water. It might also be found advisable to carry overhead tracks along West Street for short distances, so as to provide better connection with piers and warehouses.

Mr. Tompkins.

E. De V. Tompkins, M. Am. Soc. C. E. (by letter).—The development of the Port of New York presents at this time a subject of peculiar interest, not only to the Engineering Profession, but to those whose business interests are affected by its facilities, and to the many who are handicapped so seriously by the present intolerable congestion of the Lower West Side Manhattan water-front.

Mr. Cresson's paper ably presents the solution of the latter problem, as reached by the engineers of the Dock Department. The following remarks are offered, not in a carping spirit, but in the hope that

Mr. Tompkins. sincere criticism may induce the author, in closing the discussion, to reply.

It is stated that Greater New York has a water-front of about 450 miles, the entire frontage of Manhattan alone being about 30 miles. Comparatively speaking, the water-front of Manhattan, however, is fully improved with more or less modern piers, and a large percentage of its marginal way is intolerably congested, while the 400-mile water-front of the other four Boroughs is practically in its natural state.

The plan described in the paper would be a most excellent scheme for retaining in Manhattan for another twenty-five years all its present industries; but, while of benefit to one borough, would it not retard the development of the city as a whole? Many manufacturers, seeking the advantages of this proposed elevated freight railroad, would flock from other parts of Manhattan to the water-front, and the congestion would soon be even greater than it is at present, on both the land and water sides of the marginal way.

It was stated in the oral discussion of the paper that appliances for the mechanical handling of freight could be readily installed in one of the proposed terminal buildings occupying a block, say, 200 ft. square, which would have a capacity of handling 800 tons per hour, assuming 1 ton to each truck. Installation of machinery of this capacity may be easy of accomplishment, but how could 800 trucks per hour reach the building? These proposed buildings are to be located on the land side of the marginal way. Probably all these trucks would enter on one side of the building and leave on the opposite side. This would necessitate the passage of 1 truck through the approach street every 4 sec. Even if the trucks could enter on two sides and leave on two sides of the building, a rate of 1 truck every 8 sec. would result, which is far from practicable.

If the scheme of the Dock Department were to be carried into effect, and used by all the railroads, the City of New York would then consist of four boroughs practically no more developed than they are to-day, and the Borough of Manhattan, indescribably confused and congested. Here would be huddled together office buildings, factories, hotels, and a great rail and water terminal for freight as well as for passengers.

Under the present congested conditions, industries now operating in Manhattan will soon be forced to seek accommodations in other parts of the Port, and the time is ripe for the development of great industrial centers along the 400 miles of unimproved water-front. Many ideal locations are to be found here, suitable for such terminals, which could have several railroad connections to the very doors of hundreds of factory buildings, with ample space available for all sorts of industries. Rents would be cheaper than in Manhattan, both

Mr. Tompkins.

for manufacturer and employee, and the latter could live in more open and healthier surroundings. The congestion along Manhattan's water-front, therefore, might best be relieved by offering such attractions at other parts of the Port.

If, then, as the time is ripe, every inducement be now made to encourage the private and municipal development of great industrial centers uniformly over the four boroughs, as best suited to the conditions of each, the City of New York will consist of the Borough of Manhattan, the oldest and most centrally located, the executive center of the City, built up with office buildings, residences, hotels, and stores, and the passenger terminal both of railroads and steamships, the four other boroughs being the industrial district of the great City and the terminals for all freight, whether by rail or water.

The author, in remarking on the natural advantages of the Port of New York, does not mention its second great entrance, namely, Long Island Sound. This oversight is quite common, probably due to the general habit of considering Manhattan as the whole of New York City. As the present obstructions to navigation in the East River limit the use of the Sound as an entrance to Manhattan, the advantages of its use to vast water-front areas in the Boroughs of Queens and the Bronx have been, perhaps, unappreciated. It is not generally known that to-day vessels, even of the *Oceanic* size, can safely navigate the Sound about as far as 150th Street and the East River at any stage of the tide. With the completion of the $37 000 000 project now before Congress, for the removal of the obstructions in the East River, all boroughs of the city will benefit by this second entrance to the Port.

While the writer agrees with Mr. Cresson that all steamship passenger traffic to New York should be handled in the Borough of Manhattan, and that piers of necessary length should be permitted to accommodate it, he does not believe that the immense volume of freight should be handled there, but that this should be diverted to other parts of the harbor where there are extensive unimproved areas for industrial development under more suitable conditions than obtain in Manhattan.

The most serious congestion is caused by the trucking, and it is also the most expensive item in the handling of freight. This is due largely to the retention, at this late day, of that almost obsolete means of transportation, the horse; and, is not the existing method of shipping, which requires each shipper to hire a truck to haul his freight from the factory practically direct to the freight car, almost as absurd as it would be to require each passenger to hire a truckman to haul his trunk from his house to the baggage car of his particular train? Were this latter method of handling passengers' baggage exclusively followed, intolerable congestion and expense would certainly result.

Mr. Tompkins. The rapid increase in the size of modern steamships has been most remarkable, but their development cannot be compared to that of the commercial motor-truck. In this latter lies in part the solution of the freight transportation problem in Manhattan. The freight of this borough should comprise only foodstuffs and materials for the personal needs of its inhabitants. Such direct rail connection as may be necessary for this can be provided by an elevated freight railroad built for the exclusive use of the New York Central Railroad at its own expense. To compete with this, other railroads would soon build, at most convenient locations throughout Manhattan, terminal buildings for receiving and distributing such freight. The railroads would transport the freight between these buildings and their railroad yards by their own motor-trucks. The upper floors of these buildings could be leased for light industrial purposes, and revenue could be derived therefrom. While with horse-drawn trucks it is desirable to run cars within, say, 2 or 3 miles of the destination of the freight, with the motor-truck 15 or 20 miles will be covered in less time with three times the load.

It may be readily seen that a large percentage of freight may be handled without passing through these terminal buildings at all, but can be delivered by the railroads directly at the door of the consignee. By using the motor-truck for this purpose no costly subways, elevated railroads, in fact, no expense at all would be incurred beyond the equipment. Certain longitudinal streets at least should be allotted for traffic of this particular class, though not necessarily restricted to it. These streets should be suitably paved, and sane speed regulations should be adopted. For this proposed method of transportation between the railroad yard and the distant distributing points in Manhattan, a train will be made up (for night work at least) consisting of a single motor-truck (with its operator and mechanician) and three or four trailers.

The body of each motor-truck and trailer, with its incoming package freight, can be readily lifted from the chassis at the terminal building. At the latter the shipper's freight has been classified and loaded into empty truck bodies, and one of these will immediately replace the loaded body just delivered. The motor-truck will take this to the railroad yard, where the body will again be shifted with several others from the motor chassis to a skeleton railroad car, and when this car reaches its destination, the body will again be shifted to the railroad's motor-truck in this town and thus distributed without the package freight having been handled since it was classified at the terminal building in Manhattan. In the future, therefore, the railroads would establish free "motorage" as well as free "lighterage" limits.

Were this method adopted, the proposed North River Bridge would immediately become of inestimable value to the railroads now having their freight termini on the New Jersey side of the river, as well as for vehicular traffic in general, for interstate surface railroads, and for an interstate highway and recreation place for pedestrians. Mr. Tompkins.

To conclude, it is suggested:

First.—To locate on the undeveloped 400 miles of water-front of the Port long piers, supplied with railroad tracks for through freight, and equipped with best possible mechanical handling appliances, also modern factory buildings and warehouses immediately adjacent thereto, thus attracting manufacturers and shipping away from Manhattan.

Second.—The New York Central will provide one all-rail route to the lower part of Manhattan.

Third.—To install a well-devised system of motor-trucks to take care of its share of the greatly reduced traffic that would result under these conditions.

It is well known that any and every plan which tends toward the improvement of the Port of New York will have the hearty co-operation of the present administration of the Dock Department. It is desirable that there should be a thorough discussion of Mr. Cresson's paper and constructive criticism made of the same. Engineers, in particular, should devote much thought to the subject, and should aid the present Commissioner in his efforts to create an overwhelming public demand for immediate action.

A. W. Robinson, M. Am. Soc. C. E. (by letter).—To provide adequately for the expansion of the Port of New York is a problem which no one man can solve, and it is by hearing all the interests involved and inviting discussion from engineers that those charged with this work can obtain data and suggestions from which finally to evolve an acceptable plan. Mr. Robinson.

The mixture of the various kinds of traffic in large cities, which in early days presented no difficulty, has with growth produced conditions which are wasteful and illogical. Follow the course of a shipment of goods arriving in New York until it reaches the consumer or retailer. After being extricated from the chaos at the ship's side, it is carted by horses through the streets over stone pavements and dumped on the sidewalk in front of the wholesale merchant's premises, being obstructed and obstructing others at every step. The operation thus far has taken as long and cost as much as the sea journey of 3 000 miles. After a more or less prolonged stay, during which it accumulates more delay and added cost, it is shipped out by a similar process to the consumer or retailer. The trucking in city streets would be greatly reduced if only freight for consumption in the city were handled, and all through freight and traffic of wholesalers destined

Mr. Robinson. for points outside were handled in some other way. The horse-trucks and rough stone pavements are also archaic, and motor-driven trucks on smooth and level pavements built specially for them would be far more efficient.

As Mr. Cresson has pointed out, the large steamships must be provided for in a central position. The rapid and cheap handling of ingoing and outgoing freight to these vessels is essential, and it should be kept off the street, except for local requirements.

Most schemes which have been proposed contemplate the construction of largely increased railway facilities on the dock front, and the continuance of the present system of car-floats, or a further development of tunnel systems. For steamship freight in transit, both ingoing and outgoing, the writer would suggest that the car-float system be expanded so as to constitute floating warehouses into which cars could be run. Such floating warehouses should have ample floor space on two decks and complete mechanical freight-handling appliances. They would perform all the functions of fixed sheds on the pier, but be carried on steel hulls instead of fixed foundations, and have the advantage of making a connecting link between the ship and any railroad with the least delay and expense. On the arrival of a vessel at her pier, one of these floating warehouses would go alongside, and the receiving and discharging capacity of the ship would be doubled. The lower deck could carry sixteen or more box cars in addition to large floor space level with the floors of the cars, and have complete mechanical loading and unloading appliances. The loading and unloading of these cars could be done while the vessel was changing position, so that on arrival at a railway the cars would be ready to proceed as from the present car-float.

As most of the large steamship piers are now without direct railway connections, and have no means of getting any except by further congestion on the landward side, it would seem worthy of consideration to expand the car-float system in some such way.

It would seem reasonable to avoid bringing into the city any freight which is not destined for consumption there and to minimize trucking by the establishment of large terminal buildings in an attractive locality, for occupancy of business firms as tenants, and supplied with shipping facilities without trucking.

The development of the outlying portions of the harbor is a vast problem almost untouched, and, as Mr. Cresson says, offers a wealth of opportunity. It is to the development of these regions that New York must look to provide facilities for commerce other than local. These outlying spaces will immediately become much more valuable when quick passenger communication is provided by electrically operated tunnels, with Lower New York as the nerve center.

Mr. Robinson.

The vast areas of the Hackensack Meadows, the shores of Newark Bay, the west side of the Upper Bay opposite Bayonne, the lagoons of Rockaway, and other places offer opportunities for the creation of many square miles of real estate at a nominal cost. There has been some filling in of the Hackensack Meadows in a desultory way and with slow and costly methods, and what is urgently needed now, before any more work is done, is a comprehensive and authoritative plan covering all these districts, to provide for all needs and to represent and conserve all interests involved. In this way all work should be a part of a systematic plan, and not have to be undone later.

It may be of interest to note what is being done, in the way of harbor improvements and land reclamation, at Bombay. The Port Trust of Bombay is carrying out extensions which include the conversion of tidal flats into a large inner basin, at the same time, the adjoining land is being reclaimed with the spoil. For this purpose two powerful hydraulic dredges of special design have been constructed, of 3 500 h.p. each and capable of dredging 25 000 cu. yd. of soil per day and delivering it at a distance of 4 000 ft. These dredges are fitted with powerful cutters and suction apparatus designed by the writer, and can cut their way into a solid bank, making a channel 500 ft. wide and 35 ft. deep at one time. The cutter is similar to a gigantic milling tool with steel blades, and cuts a section of from 60 to 70 sq. ft. at a rate of from 30 to 60 ft. per min., according to the hardness of the soil.

There are no dredges on the Atlantic Coast at the present time at all competent to deal with land reclamation works of any magnitude. The unit cost at which such work has been done in a small way heretofore would be prohibitory, but with modern tools of large capacity, adapted to the conditions, these large projects become much more reasonable, and indeed are rendered possible where before they would have been impossible.

Hydraulic shore discharge work for land reclamation has usually been done with small dredges having discharge pipes not more than 20 in. in diameter, so that they can be readily handled and shifted by manual labor. As the pipes in large modern dredges are not handled by manual labor, they can be made of large size, say, from 42 to 48 in. in diameter. The tidal rise can be utilized to lift and move the pipes to a new location, and the land can be built out from shore by a suitable terminal pontoon carrying a long overhang. A terminal pontoon of this sort, with an overhang of 220 ft., was used by the writer in making shore deposit on the Upper Nile. In this case the advance was rapid and continuous; there was no manual labor and no delay due to the shifting of pipes.

These brief references will serve to show that the capacity of

Mr. Robinson. modern tools for dredging and land reclamation has an important bearing on the development of the outlying regions of New York Harbor; and, in order to get the best results, the improvements should be designed in conformity with the capabilities of these modern tools. For instance, advantage should be taken of present depth of water, as far as possible, and favorable material should be chosen for the maximum excavation. The distance from cut to fill should not exceed 4 000 ft., for economy at one handling. Under favorable conditions, one of these dredges will reclaim 2 acres per day with a fill of 6 ft.

Mr. Thomson puts forward a bold plan for the reconstruction of the harbor, and some of his remarks are very pertinent. His criticism, that the proposed railway belt line would not relieve congestion, but rather promote it, appears to be well taken. His plan of extending the city 4 miles into the bay, while it would create much valuable real estate, seems open to serious objections. The water passage around the Battery is one of the most thickly traveled in the world, and the navigation interests would never permit it to be closed. Furthermore, the bottle-shaped extension would cause a density of traffic at the neck of the bottle which would be hard to overcome. Mr. Thomson has also located much of his land fill in from 60 to 70 ft. of water, in the main ship channel, which it would be a pity, as well as wasteful, to spoil. His "New Governor's Island" is also located partly in the old ship channel, which has been dredged at great cost. It is easy to draw lines and create new continents and islands on the map, but, nevertheless, the subject is worthy of the most careful study. Without doubt the present contours of these outlying districts could be materially changed for the better, and the cost would be but a small proportion of the increased value, if systematically carried out with modern tools.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852.

PAPERS AND DISCUSSIONS

THE HALLIGAN DAM: A REINFORCED MASONRY STRUCTURE.

Discussion.*

By Mr. G. N. Houston.†

G. N. Houston, M. Am. Soc. C. E. (by letter).—In presenting this paper the writer had no intention of discussing the work done previous to his connection with the dam, except in a very general way. The statements regarding the cost and yardage in the foundations were based on data on record in the office of the company, which the writer assumed to be accurate. He is glad that Mr. Swigart has corrected these data from notes in his possession. Mr. Houston.

In regard to the material left on the ground by the first contractor, the writer found 800 cu. yd. of sand, 1 244 cu. yd. of quarried rock for the crusher, a considerable portion of which could not be used on account of its quality, and about 900 bbl. of cement. The company purchased all machinery, tools, and material, except cement (which was already its property) from the first contractor for $2 750, and sold the same, together with all stone, sand, and lumber on the site, reserving the caretaker's house and cement house, to the second contractor for $4 500. The cement, nearly all of which was in good condition, was sold by the company to the second contractor for $2.65 per bbl. The old quarry from which the stone for the crusher had been taken was not used, as it was in an unfavorable position, being about 50 ft. below the crusher, with a sharp uphill haul; but another quarry was opened about on a level with the crusher, with a haul which did not exceed 150 ft. It was also found necessary to open another quarry for the larger rock at a more advantageous point.

Using the profile on which the dam was finally constructed, there would have been about 12 150 cu. yd. of masonry in the proposed con-

* Continued from February, 1912, *Proceedings*.

† Author's closure.

Mr. Houston. struction above Elevation 0. The lowest bid received for this work was $6 per cu. yd., which would amount to $72 900. In the structure as built there were 10 628 cu. yd. above the same elevation, which, at $6.25 per cu. yd., cost $66 425. Below Elevation 0 there was a saving of about 101 cu. yd. at $6, which amounted to $606, thus making a total saving of $7 081.

With regard to the analysis of stresses, the writer does not recommend the details of this discussion as the method to follow in all cases, although in this case he believes his assumptions were on the side of safety, as the results were checked by all the common methods. However, the general method of determining the safe load for the dam considered as a gravity section, and assuming that the remainder of the actual load is carried by the arch, as one extreme, and then considering the whole load to be carried by the arch action alone, as the other extreme, will indicate the limits between which the actual stress will probably lie. With the present uncertainty in regard to the actual distribution of stresses in an arch dam, no one method of analysis should be relied on to fix the profile, but great care should be taken to check the results by as many forms of analysis as possible, and also by comparison with existing structures.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

ROAD CONSTRUCTION AND MAINTENANCE.

An Informal Discussion.*

BY MESSRS. JAMES OWEN, PAUL D. SARGENT, THEODOR S. OXHOLM, F. C. PILLSBURY, J. A. JOHNSTON, CLIFFORD RICHARDSON, W. W. CROSBY, ARTHUR H. BLANCHARD, SAMUEL WHINERY, H. P. WILLIS, E. A. KINGSLEY, L. B. SIBLEY, D. E. MCCOMB, W. A. HOWELL, FRED. E. ELLIS, P. P. SHARPLES, HAROLD PARKER, C. J. BENNETT, A. S. BRAINARD, G. IMMEDIATO, A. F. ARMSTRONG, E. H. THOMES, GEORGE W. TILLSON, R. B. GAGE, AND FREDERICK DUNHAM.

DRAINAGE AND FOUNDATIONS.

Mr. Owen.

JAMES OWEN, M. AM. SOC. C. E.—The practice of road foundation is, to a large extent, crystallized, and it would seem that all that is necessary is to get an idea of what is fairly good. On the question of drainage, it may be recalled that, at one of the National Road meetings, the Minister or Commissioner of Roads, of Ontario, laid down three fundamental principles of road construction: First, drainage; second, drainage; and third, drainage. He was asked afterward what he would do if he lived in Arizona, where there is no rainfall. From this, it can be reasonably understood that drainage is: first, a matter of climate; second, a matter of topography; and third, a matter of soil. In discussing these subjects, it is best to consider the question of drainage *per se*.

There is no doubt that in 90% of the country there is sufficient rainfall to require the consideration of drainage, and that where there is lack of rainfall there are not many roads; consequently, drainage is a factor in road construction.

The problem can be divided into two: the removal of surface water and the removal of underground water. The assumption that the average macadam surface is water-proof at all times is not maintained

* Continued from March, 1912, *Proceedings*.

Mr. Owen. by facts, and cannot be relied on as a basis for practical construction. It is possible, with a clean, unbroken surface, consolidated by constant travel into a homogeneous mass, that after a dry spell the first rainfall would be shed; but, after a continuous soakage, all broken stone becomes somewhat loosened and this makes the matter of drainage a bad proposition.

Water on highways can be shed in three different ways: First, by the crown in construction; second, by the grade after the crown is constructed; and third, by a discharge into some natural watercourse.

The question of crowning has been rather a matter of controversy, and the speaker's practice varies according to location, grade, and amount of travel, and also according to the character of travel. The question of trolley tracks on roads has also to be considered. On a country highway with a single line of travel, the best practice has always been to build the crown about 2 in. higher than is ultimately desired, as the work is green, to a certain extent, and, if allowance is not made for the first settlement, there is a likelihood of a flat surface in the center where water will collect.

It has been the speaker's practice to increase the crown gradually until, on a new 16-ft. road, it is 5 in. This will be compacted to about 3 or $3\frac{1}{2}$ in., which is good average practice. In suburban towns, or on roads where the travel is divided or heavy, the necessity for so great a crown is not apparent. Where there is a trolley road, the crown is practically eliminated by the track in the center, and from it a slope has to be built to the gutter. That slope is, of necessity, reduced to a minimum, and the speaker has found that, in repairing roads along trolley tracks, an artificial crown of about 1 in. or $1\frac{1}{2}$ in. will finally wear down to a normal slope sufficient to shed water.

In considering crowning, there is always the question of the grade of the road. As a rule, it must be understood that the steeper the grade, the greater the crown. If there is a 10% grade, with an ordinary flat crown, the tendency of the water in a heavy rainfall is to follow the grade rather than the crown, or, at least, to make a curve in its final discharge; but in such cases it is always better to make a rather higher crown.

There is great objection to the high crown in thickly populated districts, due to the sliding motion of the vehicles, and also to the extra strain on the lower part of the wheels. Consequently, it is desirable to eliminate the crown as much as possible in consideration of this excessive strain.

When there is a bituminous surface, or even an oily surface, a flatter crown can be used than with ordinary macadam. On country roads the shedding of the water to its final outlet is generally done in the gutter. It is a better practice, and a matter of economy, even on such roads, to provide the drain pipes or sewer pipes along each

side with inlets at intervals of about 400 ft., so as to gather the water and prevent a great rush. Mr. Owen.

Springs in the roadbed have to be treated according to the special conditions. The speaker wishes to emphasize particularly the fact that sometimes an undue amount of money is expended and care taken to provide for what, during construction, seemed to be a spring in the bed of a road. If there is a cut of 12 or 15 ft. in a gravel pan, it generally contains a spring, and the usual procedure is to make elaborate efforts to remove the water permanently. The speaker has found, however, after considerable experience, that the first rush of water is merely a lowering of the water-level to the new grade, and that frequently within a year or two such springs disappear entirely. Consequently, the money spent to take care of them was practically wasted. Therefore, the topography of a locality where there are springs should be considered, and judgment should be used in determining whether a spring is permanent or whether it is merely due to changing conditions in constructing the road.

In regard to grades, the speaker has always insisted that a flat road should never be built. In some localities it is almost impossible to accomplish this; but, where it is possible—and in ninety-nine cases out of a hundred it is—it is better to build the road so as to shed the water longitudinally rather than continuously sideways. The ordinary level macadam road may be rounding in its first construction, but the travel will wear off that rounding and there will be a depression in the travel line, where water will gather, soak into the road, and make a bad rut. In a long stretch of level country, it is sometimes difficult to undulate the road from point to point with a minimum fall of $\frac{5}{10}$ in. in 100 ft., but it is better practice than to have a level surface.

As to the question of limiting grades, the speaker's standard for a road is between 1 and 2 per cent. The former gives a very efficacious result. Less than 1% causes a retardation of the natural flow of the water, and such roads require more slope to conduct it to the gutter. More than 2% and up to 4% is a good traveling grade, and has been the speaker's standard for such purposes.

Another question enters here, which, while not related to the grade itself, is worthy of consideration. The first proposition was that on traveled roads, where there is a height of a certain number of feet to be overcome in a certain distance, a certain grade should be adopted. It has been the accepted practice for years to limit the grade to the lowest possible through rate. As a matter of fact, the question of time is a factor as much as that of load. If there is an 8% grade, the horse will have to walk up that grade with his load; but if it is cut into two grades, say of 2% for a section, with the remainder steeper, the horse can trot on the low grade, gaining time on that part of the

Mr. Owen. road, and can walk just as fast up the steep grade as up that of 6%, which is an important matter where time is a consideration.

This same rule would apply to automobiles, and it seems fair to presume that with automobile travel, and also with auto-truck travel, there should not be so much insistence on low grades. A great deal of money has been spent in cutting down hills, and making deep cuts and fills in order to produce a low minimum grade. It makes very little difference to the average automobile, except as a matter of time and some shifting of gears, whether it goes up a 2% or an 8% grade. Consequently, this question has to be decided from the standpoint of the amount of travel and the character of the traffic.

One little point in the question of drainage is the problem of handling quicksands. In one case, in the speaker's experience, a road went through a very bad bed of quicksand. An open trough of wood was constructed with battens on the top and open at the bottom. This was laid on the quicksand, and the men stood on it and dug out the sand. As the trough gradually settled into place, it was filled with stone, and provision was made for an outlet for the water at the end. That piece of road has never stirred since it was laid thirty years ago.

The frost line, of course, is a vital question in drainage, as it is in all road construction. It relates more particularly to foundations, but the speaker wishes to emphasize the fact that in the consideration of all road construction, the question of temperature, where there is no frost in the ground and no obstruction to the underground flow of water, is very important; but where the frost is 4 or 5 ft. deep, breaking up the homogeneity of the road and coming out at the surface, with, say, 1 ft. of melted earth on the top and 2 ft. of hard frozen ground below, it makes the most undesirable proposition that can be considered, and these conditions will obtain almost all over the northern part of the United States. Here, naturally, rises the question of foundations. For a number of years, the speaker has been rather a lonely man in road construction, and has persistently and constantly advocated foundations. He has built very few macadam roads, and is very glad of it. He has built some, and has then taken them up and rebuilt them with foundations, and to-day, after a series of years spent in road construction and maintenance, is perfectly satisfied that, finally, whatever little extra cost was incurred originally in building foundations is counterbalanced by the smaller maintenance expense.

In two communities, in the same locality, with about the same population, and the same travel, a series of roads was built. One community built its roads with foundations, and the other thought it could get along and spread its money a little farther by putting down macadam. The final result confirmed the speaker's views, as the macadam roads broke up in a few years and necessitated a large

expenditure to put them in proper shape. Some telford roads, built 6, 7, 8, 9, and 10 years ago, have stood up without a break, and, in one case, where a road was built of telford, it did not receive a dollar's worth of repairs in 19 years, and it was a heavily traveled road. Mr. Owen.

The speaker has adopted a principle which he has found to be fairly successful, namely, to make the thickness of the pavement according to the grade. The following data were established as a basis: Less than 1%, a 10-in. pavement; between 1 and 4%, an 8-in. pavement; and greater than 4%, a 6-in. macadam; and it would seem that such a principle might be taken as a governing one in considering the case of foundations for road construction.

The telford pavement has, or should have, if the construction is fairly good, a system of drainage of its own. Such a pavement is supposed to be in reality a drain to the bottom, after which the water has to be carried away to the lowest point.

In the question of foundations for future work, another element is intruding, which will require careful consideration, namely, the auto-truck. This auto-truck will take a load of, say, 5 tons, and weighs 5 tons itself, that is, 10 tons on four wheels, and if a road is constructed of 6-in. macadam, and is allowed to wear down to 3 in., and in some cases 2 in., the inevitable result will be that the auto-truck, or even any other heavy load, will break through, and the road is gone.

The question of cost is material. In the speaker's district, there is plenty of stone, and telford roads are built as cheaply as macadam roads within the same locality; but any frost-proof stone can be used in foundations, and the speaker has laid many miles of sandstone foundation and obtained good results from the roads. The great trouble at one time was the desire to spread the money over as long a distance as was possible—to obtain quick results—and this idea continued for a long time, and led to less care, from a purely engineering standpoint, than if the future had been considered. To-day that issue is not regarded as important. The public mind at large has wakened up to the necessity of good roads. It has been educated. It is easier now to get the amount of money necessary to make good roads, and if the practice can be crystallized, the United States will have as good a system of roads as any in the world.

Paul D. Sargent, M. Am. Soc. C. E. (by letter).—The writer can heartily agree with all that has been said as to the necessity of thorough drainage and, as nearly as possible, a perfect foundation on which to lay any kind of a road surface. There is one kind of foundation work with which engineers sometimes have to deal, namely, that for a roadbed across a swamp or bog. Mr. Sargent.

The writer, while State Highway Commissioner of Maine, constructed two sections of improved road over bogs which were very

Mr. Sargent. quaky and unstable. In each case the work was really widening an old road. In one section the center line of the new road coincided with that of the old one; in the other, all the widening was on one side of the original road. In both cases the bearing power of the bog was improved by the construction of a brush mattress under the new fill. For this work, boughs of pine, spruce, fir, or hemlock, were used, care being taken to exclude those having stems more than 2 in. in diameter. These boughs were laid shingle fashion in courses, first crosswise and then lengthwise of the road, and were four courses deep, that is, two transverse and two longitudinal layers, the total depth being about 16 in. On the boughs was placed a 2-ft. fill of gravel. One of these roads was built in 1908 and the other in 1910, and, to the writer's knowledge, not the slightest settlement of the foundation has occurred. Both bogs were so bad that it was impossible to drive a horse across them, and even a man jumping would shake them for a radius of 50 ft.

This method of building a foundation was also used on one section of new county road, constructed under the jurisdiction of a board of county commissioners, where the bog was so bad that, even after the mattress was laid, it was necessary to unhitch the horses and draw the wagons out on the mattress with a tackle and fall before they could be dumped. After this road had been built about two years, reports indicated that it was in perfect condition, and that large loads were being carried over it.

In work of this kind, it is absolutely necessary that the turf or sod be not cut. If it is, and much of a load is superimposed, settlement will almost certainly occur. The writer has never tried laying a macadam road on one of these roadbeds, but has no doubt that, after the roadbed has been in use for a few years, a macadam surface could be laid on it, if a light roller was used for consolidating the crushed stone.

Mr. Oxholm. THEODOR S. OXHOLM, M. AM. SOC. C. E. (by letter).—During the past 14 years the writer has had charge of the construction of many miles of first-class water-bound macadam roads in the Borough of Richmond, City of New York. Previous to that, some good roads had been constructed by the county, with telford foundations. When repairs were made to these latter roads, it was found that the upper or wearing surface, composed of the smaller sizes of stone, was badly worn where it came in contact with the telford; this appeared to indicate that the wearing surface was being worn, both at the top by vehicles, and at the bottom by the impact on the heavy telford stone, thereby causing an increased expense for maintenance.

It has always been the writer's theory that, in any kind of macadam road construction, telford or field stone should only be used for drainage purposes; that on dry and well-drained soil, the ordinary

macadam road, composed of stone ranging in size from 2½ in. to screenings and dust, is suitable for all classes of travel in country districts, where such roads are mostly built. The resiliency of the soil and the pavement itself (provided it is built of sufficient thickness, and under proper specifications), should protect the road from serious damage by the heaviest trucks. Mr. Oxholm.

It has been found in this Borough that large sums, formerly spent for unnecessary drainage, could be saved by constructing the road, in most cases, where the conditions appear to be favorable, without any special provisions for drainage other than well-cleared ditches at the sides, having suitable outlets at the foot of grades, and by noting frost heaves or other damaged sections during the winter and spring, and, in these places, which are comparatively few, building blind drains of stone from the center of the road diagonally to the ditches or culverts.

It has also been found that well-built tile drains, or flat stone drains, have a tendency to fill up in a few years and become practically useless, so that where such drains are actually necessary, much more care should be taken in their construction.

F. C. PILLSBURY, M. AM. SOC. C. E.—There is no doubt about the necessity for adequate drainage on all roads, whatever the surface construction may be. Drainage and foundation problems, however, are varied, and their solution depends so much on natural conditions above and below the surface, as well as on variations in climate, that set rules, formulas, or plans should be prescribed carefully, as they would not be equally effective under different conditions. Frequently, there appears to have been an unnecessary expenditure for drainage and foundations by the use of so-called telford and stone V-drains. The speaker has frequently noticed places where such foundations have been used with apparent lack of judgment; places where these types of foundations were not necessary at all, or where some other materials, such as gravel, cinders, slag, etc., might have been used, at a much lower expense. He has also seen stone foundations used where they could not give good results unless laid on sand or sandy gravel. The speaker's experience has been, that for surfaces which are not subjected to extremely heavy loads, such as would require granite blocks or similar pavements, a sandy gravel provides a better foundation than telford or V-drains, under any natural conditions. Without adequate foundations and proper drainage, even the best surfaces fail. In fact, many failures which have been attributed to other causes have been due to this. Mr. Pillsbury.

J. A. JOHNSTON, M. AM. SOC. C. E.—State roads have been built in Massachusetts for 17 years. The speaker has been connected with the work from the beginning, and for the past 15 years has been a Division Engineer, with jurisdiction over construction and maintenance in about one-fifth of the State. Mr. Johnston.

Mr. Johnston. In beginning its work, the Commission constructed some rather elaborate systems of trench drains and telford paving for foundations. Where such work was done there were no failures, but the cost was excessive. Such foundations were not built everywhere, but, on the contrary, the policy was to build them only where they were thought to be absolutely necessary, and to omit them in case of doubt. In view of the expense, the speaker believes that this theory was correct, and especially because at first greater reliance was placed on blind drains than has since been found to have been justified. Of course, it was expected, if the need developed, to build such additional drains and foundations as were required.

It has been the speaker's practice to locate carefully every frost break and soft spot which shows on the road in the spring, and to remedy such places as promptly as possible. It has been difficult at times to persuade some of the past members of the Commission of the necessity for such work. Some of them have believed that it was a mistake to disturb the crust of a road.

To avoid breaking up this crust, many experiments have been tried. On one section of macadam road, which was so muddy in the spring that the crust had the consistency of porridge, from 6 to 8 in. of broken stone were placed on what had originally been 6 in. of macadam. This improved the conditions for one season, but in the second year they were as bad as before applying the remedy. This section was at the foot of a hill and on a fill about 2 or 3 ft. above meadow land. A blind drain, 2 ft. wide and 3 ft. deep, was then built across the upper end of the fill to cut off the ground-water from the hill, but it had very little effect. Similar cross-drains were then constructed at about 100-ft. intervals, but the road continued to be muddy. After that the macadam was stripped off and a foundation, 12 ft. wide, 18 in. deep in the center, and 6 in. deep on the sides, was built with field stones not exceeding 10 in. in their largest dimension. The old broken stone was then screened and replaced, but so much of it had been churned into the mud, that though from 12 to 14 in. had been placed on this road, scarcely enough was recovered to cover the foundation. Since this work was done, 5 years have elapsed, and there has been no further trouble.

Miles of ground-water drains have been built which the speaker now believes to be practically useless, for it is his opinion that under many conditions the capillary action of the soil, intensified by the puddling or tamping action of the traffic passing over a road surface, nullifies, to a large extent, the supposed effect of the drain in lowering the water-table, and this is regardless of the fact that there may be a water-proof top on the road. The speaker has built blind drains entirely around a section of road, 15 ft. square, and with proper outlets, but with no appreciable effect on the enclosed section. He does

not absolutely condemn these drains, for there are soils which can be drained, and there are places where an excess of water must be taken care of, but there are many instances where more money has been spent on drains than would be required to build an absolutely unyielding foundation under the entire road. Mr. Johnston.

Under most conditions, a 10-ft. foundation of stone, even 6 in. deep, which will seldom cost more than 25 cents per lin. ft. of road, is of immeasurably greater benefit than a single drain which will cost more money. To hold up a road surface by strengthening the foundation may not sound as scientific as by the more indirect method of drainage, but it is far more successful. By a stone foundation is not meant the hit-or-miss dumping of stone into mud holes, nor, at the same time, is it essential to hit each stone on three sides with a hammer and wedge it in place as telford paving. The dirt surface of the sub-grade should be smoothed and properly graded to an outlet for the water; the stone should be placed to grade, with the smaller stones on top to close the crevices, and the whole should be well rolled. It is not always necessary to have a great depth of stone, it should be varied according to conditions, being, in some places, 18 in., and in others only 6 in. It is by no means essential that the foundation should extend the full width of the macadam. On most of the roads in the speaker's division the foundations are only 10 ft. wide, while the macadam is 15 ft. In the spring, when the frost is coming out, the average width of travel is rarely more than 10 ft., and, though the eye can readily detect the line of the edge of the foundation, there have been no breaks and no trouble from this practice.

To use more than 4 in. of broken stone for macadam is a mistake, for anything below this depth is merely foundation, and for this, field stone at $1 per cu. yd. is much better than crushed stone which will cost from $2.50 to $3 per cu. yd. On very soft soils it may be advisable to use a layer of gravel under the foundation, but a light layer of field stone over the gravel will give a far better and more substantial road than the gravel alone. In 17 years of experience, the speaker never saw a serious failure over a stone foundation which had been properly laid.

Not long ago, a road official, who had been recently appointed, told the speaker that he intended to put a telford base under all his roads. Another official, also newly appointed, stated that he did not suppose any foundation was needed under 6 in. of macadam. Unfortunately, the speaker could not agree with either of them. In Massachusetts there are many miles of road where the macadam is laid on the natural soil, with excellent results, and many more which would not have lasted one year without a foundation.

While engineers may be justified in experimenting with ordinary macadam, which can be taken up and relaid at a cost of about 14

Mr. Johnston. cents per sq. yd., it is criminal negligence to take the same chances with expensive pavements, though all have seen deplorable examples of this fault.

Mr. Richardson. CLIFFORD RICHARDSON, M. AM. SOC. C. E. (by letter).—There is nothing truer than the old adage that a road, like a house, should have a dry cellar, a firm foundation, and a tight roof. Without these characteristics a road cannot be of the highest quality, especially if the soil on which it is built carries ground-water at a depth of less than 3 ft. below its surface. There are, of course, many soils of a gravelly, sandy, or similar character, which are self-draining and do not require particular attention. The defects in most country highways which are built on clay soils, or those which do not drain themselves, can be attributed to lack of drainage. This is true, not only of the roads built in the United States, but also to a very great extent of English roads, as will appear from statements of English highway engineers to which the writer will refer.

There is probably no highway engineer who does not recognize the importance of drainage, but it is an astonishing fact that, nevertheless, very few roads are properly drained. This is generally neglected because a proper study has not been made of the character of the subsoil on which the road is built and, perhaps more so, because of the additional expense it involves. When some of our public officials state that a good broken stone highway of a modern type can be built for less than $6 000 a mile, the engineer hesitates to increase the cost to a point which will lay him open to the serious criticism of extravagance, by introducing proper drainage.

Mr. Frank D. Lyon, Second Deputy Commissioner of the New York Highway Department in 1910, stated, in a paper on the "Location and Drainage of Highways":

"Among the road builders of to-day good drainage is recognized as one of the most important considerations, whether the roads in question be of earth or those with a covering metal. No one subject involved in the construction, repair or maintenance of an earth, gravel or macadam highway is of as much importance as that of drainage."

Although he recognizes the importance of drainage, it is safe to say that most of the State highways in New York are not provided with a means which will keep their foundations free from water, and dry. Figs. 1 and 2, Plate XXXV, reveal the difficulties encountered after building a piece of bituminous broken stone road on an old waterbound broken stone surface, the crust of which was placed directly on clay. During the first spring after it had been opened to travel, when the frost began to come out of the ground, it will be seen that the bituminous surface at the center was thrown up and out of place. The situation is quite the same in most of the States, although in Massachusetts it has received somewhat more careful attention.

FIG. 1.—WATERFORD ROAD, WATER-BOUND MACADAM THROWN BY FROST, MARCH 30TH, 1910.

FIG. 2.—WATERFORD ROAD, LAID IN 1909, SHOWING JUNCTION OF GENASCO ASPHALT MACADAM AND WATER-BOUND MACADAM, BOTH THROWN BY FROST MARCH 30TH, 1910.

Mr. W. A. McLean, Provincial Engineer of Highways, of Ontario, Canada, recognizes the same situation in his country as that occurring in the United States. In a paper on the subject, he says: Mr. Richardson.

"Roads in Canada to-day are bad for the same reasons that they were bad in England a century ago, before the time of Macadam. They are drainless quagmires, swallowing the stone and gravel placed on them. Townships commonly spread stone on their roads and speak of them as being 'macadamized.' To macadamize our roads means, in the first instance, that we must thoroughly drain them by surface and under-drainage. The essential principle of a macadamized road is drainage. This was the principle advanced and introduced by Macadam, and it is the one so commonly neglected throughout Canada to-day."

In building highways, the Canadian engineers, like those in the United States, while recognizing the importance of drainage, have been and are, it would seem, unable to carry into practice the ideas which they recognize as essential in road construction.

The situation is equally unsatisfactory in England, as can be seen from the statements of a prominent English engineer, Mr. R. O. Wynne-Roberts, who, in considering the question of drainage, says:

"The first consideration in connection with all roads is that of sufficient drainage, but unfortunately there are hundreds of miles of highways without satisfactory means of draining off the subsoil water and afterwards of conveying it away; the same remark often applies even to the surface water. In the case of water bound roads—and those constitute the principal portion in this country—the presence of water or excessive moisture keeps the subsoil in a sodden condition, thereby so reducing its sustaining powers as to make it unable to bear the concentrated loads often imposed, with the result that the metal coating is deformed, disintegrated, and in some measure pressed into the soft subsoil. At the same time the displaced subsoil oozes upwards, causing the roads to be softer than before, muddy in winter, dusty in summer, expensive to maintain, and giving rise to dissatisfaction to the road authorities who maintain, and to the public who use the highway in question. Economy of maintenance of a public road is largely governed by the condition and character of the subsoil. It is highly desirable that its weight carrying capacity should be preserved and improved by efficient drainage."

Mr. G. H. Jack, County Surveyor of Herefordshire, England, in considering the subject of the improvement of the roads in his county, said in his Fourth Annual Report (1911):

"The trunk roads have not in many cases a crust thicker than 4 inches and this crust rests directly on the clay subsoil. It is possible that with efficient under-drainage and impervious surface this clay may be kept sufficiently dry all the year round, and if so, then the many troubles arising from the yielding clay may be surmounted. I do not, however, consider this a certainty with a water-bound crust, however well the under-drainage is carried out. The very fact of the

Mr. Richardson.

permeability of the surface would cause the underlying clay to yield under heavy weights in wet weather. The principal function of the drains would be to get rid of the underground water and not so much the water which falls on the surface. This can be quickly disposed of through the grips and ditches if the surface is water-proof. I do not by this suggest that under-drainage would not vastly improve the condition of the water-logged lengths of roads made under our present system. On the contrary, I have cases in mind where I know the result of deep draining would be most beneficial, and would certainly prevent the roads entirely giving way as they did in many cases last December."

These statements are sufficient indication of the general neglect in all countries of the proper drainage of highways. It seems to be a purely administrative and not an engineering defect. The engineer knows the importance of drainage, but the administrator and the tax-payer fail to recognize its necessity, and are unwilling to meet the expense which it involves.

It is unnecessary to consider here the question of how proper drainage should be carried out. The proper methods are very generally recognized, and almost any highway engineer can provide for such drainage, if the necessity in any particular case is realized and the money is forthcoming, by putting in pipe drains along the sides of the road at a depth of at least 3 ft., or deeper if necessary, to remove the ground-water, or, where large quantities of field stone are available, by blind drains in the center of the roadway at a sufficient depth. These types of drains have been discussed so thoroughly in highway literature that it would seem to be a waste of time to go into the subject at this time. Surface drainage has been given more careful attention everywhere than that of the subsoil and foundation.

Finally, a statement of Mr. Vernon M. Pierce, of the Office of Public Roads, made in a paper presented to the Second International Road Congress at Brussels, may be cited. He stated that road-builders are learning more and more from experience that, as a rule, it is cheaper in the end, and more satisfactory, to drain roads than to lay expensive foundations. It is certainly true that there can be no object in constructing an expensive foundation unless the subsoil on which it is laid is dry.

The foundation is as important an element in road construction as drainage, but a foundation is useless in a location where the subsoil carries or holds ground-water, unless proper drainage is provided. Proper foundations for roads have been neglected the world over to the same extent as drainage. It is an astonishing fact that an engineer who would not, for a moment, think of constructing a building without a foundation, will expend large sums of money for a road surface without providing any means for its support. The writer will cite some evidence in connection with this situation from statements of prominent highway engineers at home and abroad.

Mr. Jack, of Herefordshire, has something to say in his Third Annual Report (1910) in regard to his roads, which would apply equally well to many locations in the United States. He says: Mr. Richardson.

"The surface coatings of our roads are so thin and the subsoil so unstable (mostly clay) that a continuously wet autumn in some cases had ruinous effect. The passage of heavy engines over such roads caused more damage than can be readily described; it is not so much the damage to the surface as the squeezing of the subsoil which causes so much trouble. Over many miles the sides are weak and unmetalled, and consequently the passage of heavy weights tends to, and, in fact does, flatten the crown of the road, and destroys effectual drainage. Complaints have been made as to the roads being too flat in cross-fall; in many cases there is cause for complaint, but it is largely due to the compressing of the subsoil. It is certainly not due to wilful negligence on the part of the surveyors in one of the most elementary principles. Instructions have been given unceasingly for the contour to be neither too flat nor too round, but of sufficient convexity to throw off the water and sufficiently flat to induce the traffic to use the full width of the road instead of adhering to the practice of keeping in one track—a practice which greatly adds to the difficulties of road surveyors. It does not appear to be generally followed out that there should be more curvature on hills than on level roads, and consequently in many places I have noticed the water follows the middle of the road instead of taking to the water-tables."

The same situation will be found in many parts of the United States. Mr. Jack adds:

"I have been surprised to see how some of our roads have deteriorated in a single year under motor and engine traffic, and I feel sure that if we do not now take the work seriously in hand it will be a matter of remaking rather than maintenance. The time has arrived when we are forced to view our work in a very different light. It has become a labour much more arduous and calling for all the skill the surveyors are capable of, and that coupled with their constant attention. I have great faith in what can be accomplished by personal concern, and indeed, I am sure that if the human element is lacking in energy and interest we cannot hope for good roads, however much the county council spend. There appears to be a doubt in some quarters as to the extent of damage to road due to motors. I think this can be set at rest by reviewing the cost of county roads during the last ten years.

"In 2	counties	the	cost	has	increased	over 100	per cent.
" 2	"	"	"	"	"	81 to 100	"
" 12	"	"	"	"	"	41 to 80	"
" 8	"	"	"	"	"	21 to 40	"
" 13	"	"	"	"	"	0 to 20	"

"I am glad to say that Herefordshire is one of the thirteen counties showing the least increase. At the same time our Ross to Hay Road, which is one most used by motors, has increased in cost during the past ten years by 100 per cent. The paramount difficulty in Herefordshire is to be found in the unstable subsoil and want of pitched foundations."

Mr. Richardson.

Mr. Jack adds, in his Fourth Annual Report:

"The heavy cost of maintenance of the roads used by engines and heavy motors, not only in Herefordshire, but in very many other counties, arises from the lack of a firm foundation. The construction of strong roads means, of course, the expenditure of large sums of money. It is an undoubted fact that roads, like any other structure, will give way if they are not laid on solid ground. In many cases building up the surface to the required thickness (11 in.) will suffice, but in others nothing short of a proper foundation will prevent incessant expenditure and a poor road into the bargain. It is not likely that a water-bound road (which means a pervious surface) will carry traction engines when the road crust is not more than 4 in. in thickness, resting on clay, which becomes of the consistency of dough when wet. Even if deep subsoil drains are laid in such roads the clay is of such a retentive nature as to make the passage of water to the drains a very slow process."

Mr. E. P. Hooley, County Surveyor of Nottinghamshire, England, in speaking at a meeting of the Institution of Municipal and County Engineers, in August, 1911, said:

"There was hardly an inch anywhere. In the County of Notts there were just the foundations which had been put in during the last few years. If they had to start and put in the foundations of the roads in the rural districts, putting in the necessary 6 in. of foundation, plus the top material, they were going to such an expense that no council would keep it. If they could put on 3 or 4 inches of material on the top and get as good a result, they would still be considered foolish if they put in expensive foundations."

As in England, much of the difficulty with broken stone roads in the United States has been, and is, due to the subsidence into the soil of the crust of the road. In many cases the soil has not been properly prepared to receive this course, and in others the nature of the soil has been such that it would be impossible to prepare it for the purpose without very careful drainage, which has been omitted almost everywhere, or by the construction of a suitable foundation of the telford type, or one of hydraulic concrete. A concrete foundation, of course, will be more costly than one of broken stone, but a foundation of this type, 4 in. thick, will be stronger than a loose one of 2½ in. broken stone, 6 in. thick, and the difference in cost will not be a serious consideration, because the much smaller quantity of stone used in the 4-in. foundation will largely make up for the cost of the cement and sand in the concrete. A concrete foundation, when once laid, will give an asset which can be counted on for all time, while a broken stone foundation is necessarily of a more or less temporary nature, owing to its displacement under travel and its disappearance into the soil which supports it. An effort should be made, at least in the case of building those highways which are to carry heavy travel, to construct them with a concrete foundation, which will last for all time, and on which

a wearing surface can be constructed easily and economically at such intervals as may be necessary. It is evident that, as engineers are constructing for the main arteries of heavy travel, they are throwing away large quantities of money by failing to provide adequate support for the wearing surface. The result is much the same as if expensive buildings were erected without adequate foundations to support them. This question of adequate foundations is one which should receive the most attention to-day. It is one which, if neglected, will do more to hamper the development of good roads than anything else, as great disappointments must arise within a few years, when it is discovered that the fine wearing surfaces which are now being constructed are so inadequately supported that they have given no reasonable return for the cost incurred in building them, and have rapidly gone to pieces. Mr. Richardson.

Mr. Wynne-Roberts, who has already been mentioned, in taking up the question of foundations for roads, has made the following statement in regard to the situation in England:

"The foundation is an essential feature of a good road, but it has not been adequately provided on a large proportion of our highways; consequently the thin crust of metal which sufficed to carry the traffic in former days is found to fail under the present-day conditions. Great expenditure of public money has lately been incurred in strengthening such roads. Some have been reconstructed, many more have been provided with thicker coating of macadam, without remedying the evils of defective drainage and foundation. Where the subsoil is hard and dry the absence of solid pitched foundations has not a serious effect on the quality of the road, but where the subsoil is wet and yielding, true economy can only be effected by thorough reconstruction, or by employing binders—which are unaffected by dampness—with the extra layer of macadam. The county surveyor of Wilts, in his last annual report, states that where the subsoil is rock or chalk, if well covered, it will be found that the cost of upkeep of the road will be from 30 to 40 per cent. less than that with the same traffic where the subsoil is clay, green-sand and silt. Telford, Macadam, Tresaquet, and other prominent road engineers, advocated stone foundations, but even they found it was not possible, probably owing to financial reasons, to adhere rigorously to their ideals or dogmas; and if it was the case when the highways were first being constructed on scientific lines, when labor was cheap, traffic comparatively light, except on some mail roads, it will doubtless be admitted that to reconstruct these roads will tax the monetary resources of the numerous road authorities, and also of the Road Board. Still, in view of the ever increasing expenditure on these roads, due to the recent rapid development of traffic, satisfaction and economy will only be attained by judicious application of modern methods of construction and maintenance. If it is possible to render a road which is simply a thin crust of metal lying in a bed of clay, and requiring annual repairs, into one which will stand the same traffic with practically no repairs for about three years, by the adoption of the modern systems, it should not require much argument to convince the road authorities that real economy is attainable at small cost."

Mr. Richardson.

Mr. J. Fred Hawkins, County Surveyor of Berkshire, has the following to say on the subject:

"In road making, as in house building, the foundation should be the first and chief consideration. In modern road construction the formation and foundation are, no doubt, considered above all things, but this was hardly the case in the days when most of our main roads were formed for coaching and other old-fashioned types of road traffic. It is often stated that most of our trunk roads have good foundations, and in some cases it is so, this chiefly in counties where the natural foundations are of rock or hard stone, or where granite is easily obtained, and has been used as road material for years. In counties like Berkshire, however, where there is a dearth of quarries, the chief material used in forming the road was Thames ballast and local gravel; the roads can be said to have no foundations at all, thus making it impossible to keep a good surface, every ton of hard stone rolled in being almost at once swallowed up. * * *

"What would the highway authorities of those days think could they see the traffic on the Bath road to-day? In spite of the extraordinary change in the traffic on our roads, the foundations still remain the same, and it is impossible to expect those roads which have gravel foundations, and the surface of which is water bound, to stand the abnormal weights of heavy motor and traction traffic. This traffic is permanent, and is bound to increase."

The statements which have been quoted are but a few of the many which have been made, which are at hand at the moment. The general opinion of British highway engineers is of the same character as those quoted.

The following is quoted from a recent editorial on the Second International Road Congress at Brussels in an English journal:*

"We have often drawn the attention of our readers to what we consider to be a well-established fact—viz., that the modern road problem is a problem of foundation rather than one of surface. * * * In regard to drainage, roads should be designed so as to prevent infiltration of water into their surfaces, which should be made as impermeable as possible."

The situation brought about by the lack of foundations, which has always been a serious one, has been intensified by the increased weight of the traffic which is using the roads at the present time, and it is much the same in the United States as in Europe, at least on the main arteries of travel. The eventual solution of the problem will be the construction of concrete foundations for roads of this type, especially in cases where the traffic is as great as shown by the traffic censuses, as on many of the residence and less used streets of cities, where a concrete foundation is always considered necessary. As a matter of fact, as the writer has shown elsewhere, the most economical method of treating main highways which are subjected to heavy motor travel,

* *The Surveyor and Municipal and County Engineer*, August 12th, 1910.

will be by paving them with some of the various surfaces (on a concrete foundation) which are able to resist the continuous traffic to which they are subjected in cities. At first sight, this would seem to be an extremely expensive proposition, and, if it were followed, the mileage of roads which could be constructed with the money available, at the present time, would be much reduced, but eventually the situation would be largely improved. Mr. Richardson.

At the Second International Road Congress at Brussels, the following conclusions were arrived at, in discussing the subject of road foundations:

Foundation.—1. The strength of road foundations should be increased in proportion as the supporting power of the ground decreases. The foundation should have more body and resistance, the more it is exposed to internal deterioration and external wear.

2. In the choice of the system of foundation for both stone block pavements and metaled roads, due consideration should be given to the condition of the subsoils, with regard to the possibility of their drainage, to their geological nature, and to the nature of the materials of the locality. In order to determine the thickness and the extent of the foundations, the pressure per unit area should be made compatible with the carrying resistance of the soils, observed under the most unfavorable conditions.

Drainage.—3. In soils where preliminary drainage is required before the construction, the general methods should be applied to the whole or to a part of the road-bed and to the bed of the metal, if necessary.

4. The cross and longitudinal sections of roads and those of side-gutters should be established so as to facilitate the flow of water, and to prevent infiltration into road surfaces, which should be made as impermeable as possible. The evaporation of superficial dampness should be encouraged by every means.

5. The works for the foundation and for drainage should be carried out simply and economically, and by using the materials of the locality as far as possible.

Of course, these conclusions mean but little, are very colorless, and merely show that drainage and foundations were considered of importance by those drawing them.

The subject, however, cannot be too frequently brought to the attention of highway engineers and tax-payers in America, where the situation is plainly as bad as it is shown to be in England by the quotations from the statements of the authorities on road building of that country. It is to be hoped that American engineers will give the matter serious attention, for, unless these features of road construction and the economics of the problem, that is to say, the manner in which the building of roads is financed, are considered, there will be

Mr. Richardson. an enormous revulsion of feeling toward the construction of good roads when it is discovered that those which are now being built give no adequate return for the money expended.

Mr. Crosby. W. W. Crosby, M. Am. Soc. C. E.—With the development of traffic along the lines of heavy trucking, the proper construction of road foundations is more important than ever. The surfacing with bituminous material of many roads near Baltimore, Md., has invited and encouraged their use by heavy motor trucks for the purpose of bringing farm products to market.

Until recently, macadam, 4, 6, or 8 in. thick after rolling, was perhaps a standard surfacing, and proved satisfactory where there was a proper sub-grade. Even now there appears to be a general tendency among engineers, as well as contractors, to consider a sub-grade sufficient, provided it is possible to build a surfacing on it. In the speaker's opinion, however, this is not always a correct assumption.

That part of the foundation which comes next to the surfacing and is ordinarily known as the sub-grade, is one of the most important, and warrants more attention than it usually receives. If this sub-grade is not properly prepared, it may churn up into the stone when this is applied, with the result that the actual thickness of the clean stone layer is materially reduced. On bad soils, it is sometimes difficult to get the surface of the sub-grade into first-class shape. For instance, in clays, especially in those which contain considerable mica, the sub-grade, during the process of rolling, will flake after becoming partly compacted, these flakes appearing both ahead of, and behind, the roller. This condition, in the case of sub-grades in cuts, may be caused by too much rolling, but it frequently occurs on fills which the speaker is absolutely certain were not rolled too much. This flaky condition may be overcome satisfactorily by spreading a layer of sand, cinders, or stone dust, as may be convenient, on top of the sub-grade, to a thickness of from 2 to 6 in., and then compacting this layer with the roller, so as to secure an entirely satisfactory surface on which the macadam can be placed without danger of its being mixed with the sub-grade material and thus losing any portion of its effective depth.

Still another method, which has been found to be quite successful, is to use for the first course of macadam, crusher-run stone containing all the fine material. Such stone, placed on a poor sub-grade previously put in the best possible condition, is then thoroughly harrowed. The effect of the harrowing is to deposit the fine material in the bottom of the stone layer and produce apparently about the same effect as the application of a layer of sand or screenings placed by itself on the sub-grade as previously described. (It is assumed, of course, that proper drainage has been secured in all cases.)

In some localities, it may be possible to build roads under favorable conditions, for a figure as low as $2 000 per mile, but the speaker believes it to be the duty of engineers generally to resist the pressure of any uneducated, uninformed, and incorrect opinion which holds that the average cost of satisfactory roads should be anywhere near that figure nowadays, and to insist on such expenditures for first cost as will result in economy in the long run. The first cost is not a true measure of expense. Maintenance costs must be taken into account. Unfortunately, figures have not been collected with proper accuracy, nor for a sufficient length of time, to show exactly the cost of maintenance, in the long run, and what the cost of improper construction may be. If such figures were available, the speaker believes that there would be more popular support for building roads with greater first cost, and that there would be far less public demand for the cheaper roads which are generally unsatisfactory. Mr. Crosby.

ARTHUR H. BLANCHARD, M. AM. SOC. C. E.—It is the opinion of many engineers that the heavy commercial traffic to which the main county roads of England are to-day subjected will be characteristic of the traffic on our trunk highways outside of built-up areas within the next 5 years. English engineers are now confronted with the problem of providing adequate foundations for many miles of macadam roads in use. If this situation is to avoided in the United States, it is self-evident that foundations should be of such character as to be able to carry the traffic to which the road is likely to be subjected in the near future at least. It appears to the speaker that the standard of 4-in. broken stone foundation courses on certain subsoils for trunk highways will have to be replaced by 6 to 10-in. foundation courses of broken stone, or a concrete foundation, if heavy commercial motor traffic is to be carried without deleterious results. Mr. Blanchard.

During the past year the speaker has adopted a maximum crown of ½ in. per ft. for macadam roads which are to remain as ordinary water-bound macadam or are to be finished later with a bituminous surface. Under certain circumstances as low as ⅜ in. per ft. has been advised. The same recommendations have been made relative to the crown of bituminous pavements, but in cases where a smooth surface finish was assured, or the bituminous pavement was completed by the application of a seal coat, a maximum of ⅜ in. and a minimum of ¼ in. per ft. was prescribed.

SAMUEL WHINERY, M. AM. SOC. C. E.—The problem of foundations involves, of course, that of rolling. It is a fact, which some may not have observed, that the amount of rolling which any foundation will bear depends on the character of the material. Plastic clays in excavations, for instance, if they are not disturbed, are about as thoroughly compacted by Nature as they can be. Whenever a heavy Mr. Whinery.

Mr. Whinery. roller is put on such a surface, and it is rolled too much, a condition of plasticity is produced. The speaker thinks that very frequently clay foundations are over-rolled, and that the remedy is to stop the rolling the moment one notices a tendency of the surface to wave, either behind or before the roller. In his experience in preparing street foundations in excavation, a 4-ton roller has often given very much better results than a 10-ton roller.

Of course, it is not necessary to state that an adequate foundation is as essential for roads as for other structures. In his discussion Mr. Richardson has given great prominence to concrete foundations. The speaker thinks that it is quite impossible to prepare any standard and unalterable specification for road foundations. The rational practice in road construction, as well as in street paving, is to study the requirements of each particular case, and then to adapt the specifications and construction to those requirements. It has been the practice of most engineers, in dealing with concrete street foundations, to assume that practically one standard of thickness and quality of concrete may be used throughout a whole city. This is a great mistake and much money is often wasted in that way. In the first place, there are many locations which do not require a very strong foundation, but where one of concrete can be used more advantageously than any other kind. It is not necessary, however, to use the best concrete, for a very small proportion of cement may give the requisite strength. In places where cement is costly, a much leaner concrete can often be used, and where the other materials are comparatively cheap, it may be found more economical to use a cheaper foundation of such lean concrete, because the strength of a beam increases with the square of its depth.

Mr. Willis. H. P. Willis, Assoc. M. Am. Soc. C. E.—The speaker believes that the subsoil must be considered as the real foundation of the road, and that, before the road problem is solved, everybody will come to this conclusion. The principal agent in the destruction of the sustaining power of a soil is moisture, most of which gets into the road by capillarity from the sides. The ditch fails to remedy this condition, because it exposes a greater surface through which the moisture can pass in this way. All road builders agree that the surface constructed above the foundation should be impervious to water. That being so, the question is how to shut the water off from the bottom and sides in the most economical way. If a ditch is dug along the side of the road at the edge of the macadam, the natural plane is broken. If an ordinary soil pipe, about 4 in. in diameter, is laid in this ditch and covered simply by tamping back the excavated soil, whatever it may be, the conditions have been changed in such a manner as to benefit at least the roadway, as far as concerns the

moisture getting in by capillary attraction, because the water follows the broken plane. Water trying to reach the ground-water level, acts as a vertical force, and if that force can be made more than the horizontal force which tends to take it under the road, it will be of great benefit in keeping out the water. If the material taken from the ditch is a clay, and if it is puddled when filled back over the pipe, a wall which will be impervious to water will be provided on the outside of the road. The water which tends to seep into the road from beyond the pipe will meet this impervious wall, follow it down, and flow off through the pipe. Mr. Lyon, of the New York State Highway Department, has tried this method with success, and it is the cheapest treatment known to the speaker, costing about 4 cents per ft. Another method of obtaining the same result is to cover the pipe with broken stone, which answers the same purpose, and probably more effectually, but is more expensive. The New York State Highway Department is now working on a scheme whereby a trench will be dug next to the macadam, and nothing will be put in that trench but a series of vertical plates made either from clay of the same kind as the soil pipe, from asphalt and clay mixed, or, in fact, from anything which can resist the disintegration which will take place in the ground. The water will meet that plane, follow it down to the pipe, and run off. Mr. Willis.

FILLERS FOR BRICK AND BLOCK PAVEMENTS.

E. A. Kingsley, Assoc. M. Am. Soc. C. E.—No stone block pavements have been laid in Little Rock, Ark., in recent years, but the older pavements were laid in very much the same manner as described by Mr. Tillson. In the Southwest, creosote block pavements are laid almost entirely with a sand filler, the blocks being set comparatively close and the sand being put on and carefully brushed in. No expansion troubles result, and the oil in the blocks produces a practically water-proof surface. No asphalt blocks have been laid in this section of the United States. Mr. Kingsley.

Concerning brick pavements, the speaker's experience does not agree in every respect with Mr. Tillson's recommendations. There is no doubt that, where cement grout filler has been carefully put in, according to the specifications of the National Brick Manufacturers' Association, it has generally produced first-class results. It would seem, however, that there are reasons for not using it generally. The cement grout filler makes the pavement especially slippery during wet weather, and always slippery on hillsides, unless a special hillside brick is used to give an intentionally rough pavement. A bituminous filler has been found to be just as satisfactory for water-proofing a pavement as one of cement grout, and, if it is of first-class quality, there is no possibility of the pavement cracking. Again, unless there

Mr. Kingsley.

is provision for adequate expansion joints, a cement grouted street will expand at times sufficiently to crush some of the brick, and has even been known to explode. With a bituminous filler this is not possible.

The question of noise enters very largely into the use of brick pavements, and is one of the main objections to them. The bituminous filler acts as a cushion and reduces to a minimum the noise made by traffic over a brick street. The argument that a cement filled brick street is smoother than a bituminous filled street is not effective. In Little Rock, two years ago, a street was paved with brick, an asphalt filler being used. This street, under very heavy traffic, is as smooth to-day and as perfect as the best laid asphalt street in the city.

One of the most important considerations, especially in the smaller cities and rapidly growing towns, is the question of street repairs. Even the advocates of a cement grout filled pavement are the first to acknowledge that it is impossible to repair such a pavement satisfactorily without destroying the bricks which are taken out and furnishing new ones. Consequently, repairing under manholes and over plumbers' ditches becomes a difficult and expensive proposition.

This same condition exists in regard to street-car tracks. It is exceedingly difficult to construct a street-car line so that, after a reasonable length of time, it will not have some loose joints. With a properly constructed bituminous filled street, it is not a difficult matter to remove the brick and rebuild the foundation, tightening up the loose joints and rebuilding the street with the brick taken out. Had the pavement been grouted with cement, it would have been impossible to remove the bricks without destroying most, if not all, of them; it would have been a much greater expense; and it would have been necessary, of course, to purchase new brick. Since the freight rate alone on paving brick runs from \$6 to \$8 per 1 000, the amount saved in repair work becomes a very strong argument in favor of the use of a bituminous filler, especially in the Southwest.

A fact sometimes overlooked is the quality of the filler. As much care and attention should be given to the quality of the asphalt which goes into a satisfactory paving filler as to that which goes into the asphalt street. The satisfactory filler must meet all the requirements for the different conditions of temperature, moisture, and traffic. It should be applied to the street with just as much care and attention as is given to the laying of an asphalt pavement, or the filling of a street with cement grout under the specifications of the National Paving Brick Manufacturers' Association.

The third reason for using a bituminous filler, and, in the speaker's opinion, the flimsiest one, is the fact that the street can be opened to traffic immediately after the application of the filler. This cannot

be done with a cement grout filler, as the street must be kept closed for a period of from 7 to 14 days before traffic can be safely permitted. This, of course, causes a little inconvenience for a short period, but is hardly a sufficient reason for advocating the use of another material, if cement grout were acknowledged to be the best. Mr. Kingsley.

Taking all things into consideration, and summing up the arguments advanced by the Paving Brick Makers Association, the speaker—as a user and not as a maker of brick for paving—cannot concede that a street filled with a good, soft filler is not as satisfactory as a noisy cement grouted street. In the Southwest it has been found that a brick street filled with a first-class asphalt filler is far more satisfactory to the property owners and residents than a cement grouted street. If the bricks are good enough to put into a street, so that they do not need a harder material to keep them from going to pieces, the life of the pavement will be as long when filled with asphalt as with cement grout.

Recently, a prominent Ohio brick manufacturer, who is not in favor of cement grout, because he manufactures a first-class brick, sent to a number of engineers in the central part of the United States, six questions regarding brick paving. In reply to the question: "What is your opinion of a good asphalt filler compared with cement?" about twenty engineers responded, and, with two or three exceptions, the opinion was in favor of asphalt. In only two or three instances were answers received favoring a cement filler, and, in some instances, excuses were given for so doing. In only two answers a preference was expressed for cement, without any qualifications.

Another of the questions was: "Do you have any cracks, breaking up of brick or cement, or arching in streets filled with cement?" In every instance where cement grout was used or favored the answers were in the affirmative, showing that with this filler troubles were always caused by cracking or arching. This series of questions was sent by this brick manufacturer without furnishing any information as to his opinions regarding fillers, but merely as a matter of information for himself. They are given as interesting data, and certainly they endorse the contentions of those who have fought so hard for the use of bituminous filler, and against which a few brickmakers have fought just as hard.

Samuel Whinery, M. Am. Soc. C. E.—The speaker agrees substantially with Mr. Tillson's conclusions. He has been a strong advocate of cement grout filler for many years, and remains so. Mr. Whinery.

The argument, that block pavements filled with grout are more difficult to repair, does not deserve great weight, unless one accepts the definition of a prominent member of the Engineer Corps of the Army, who, when asked what was the best pavement for city streets,

Mr. Whinery.

replied, with some irony, that it was that pavement which could be torn up easiest and put back easiest. If this were the true definition of a good pavement, then, of course, the use of cement grout filler would be wrong. The fact that it costs a little more to make openings and repairs, is of small importance when compared with the aggregate life and cost of maintaining the whole pavement over the street.

In the case of wooden block pavements, an exception should be made. The joints are purposely made so small, that it is quite impracticable to get any filler other than a fine sand into them; even where a grout filler is introduced with much care, the oil which exudes from the blocks, has the effect, apparently, of disintegrating the thin sheets of mortar, and it becomes, in time, little better than plain sand. In the speaker's judgment, however, for all other classes of block pavement, under nearly all conditions, the grout filler is advisable.

Mr. Sibley.

L. P. SIBLEY, ESQ.*—There is an interesting development in the use of pitch filler for wood block pavement, which is worthy of attention. With brick and granite block, a sand cushion is necessary to provide resiliency, but wood blocks themselves have sufficient resiliency. Three years ago the street railway company in St. Louis, in paving between its tracks with wood blocks, used a new method which eliminated the sand cushion entirely. The concrete base was put in as usual and surfaced with cement mortar to the grade of, and practically at a level with, the underside of the block. When the concrete and mortar had thoroughly set, and immediately before setting the blocks, the mortar was coated with hot pitch, and, as the blocks were set, a side and an end of each was coated with pitch by simply dipping the side and end into that already on the concrete at the point where the block was to be set. In setting the blocks, the coated sides and ends were placed against the uncoated sides and ends of those previously in place, thus positively insuring a thin layer of pitch to the full depth of every joint.

The advantages of this method, apparently, are: First, the concrete base is thoroughly water-proofed; second, the underside of the block is water-proofed, and as moisture enters the block through the end of the grain, and the surface soon becomes so dense that the moisture cannot enter from the top, the water-proofing of the underside largely protects against expansion, which is the most serious defect in wood block paving; third, it provides for any slight expansion which may take place in the blocks, by having pitch the full depth of every joint; and, fourth, it insures that all the pitch shall be below the surface of the pavement, where it serves its proper function, instead of a considerable part of it being on the surface, as is the case when the joints are poured or the pitch is flushed on, thus adding to the trouble if oil exudes from the blocks.

* Asst. Eastern Manager, Barrett Manufacturing Company.

The speaker fears that some remarks with regard to the construction of brick pavements in Cleveland and Columbus, Ohio, may have created a wrong impression. It has been stated that cement grout filler is used exclusively in Cleveland. As a matter of fact, more than 5 000 000 lb. of pitch were used for filler in that city in 1911, and, based on a maximum of 15 lb. per sq. yd. for brick paving and 25 lb. per sq. yd. for granite block paving, this would provide for more than 200 000 sq. yd. of paving where grout was not used. In Columbus, where a pitch filler had been used almost exclusively up to two years ago, a grout filler was used to a considerable extent in 1911, but the latest information from that city is that this filler has not been satisfactory, and that, for the greater part of all the block paving in 1912, a soft filler will be used. Mr. Sibley.

There may be grounds for a difference of opinion as to the results obtained with grout and soft fillers in pavements which do not have to be disturbed in order to make repairs to water pipes, sewers, water conduits, etc.; but where such openings are made in a grouted pavement, the original results cannot be obtained in the repair work, unless the repaired section is closed to traffic for from 7 to 10 days, otherwise the bond in the cement will be destroyed. Since it is impracticable to keep traffic from each repaired space for so long a time, a pitch filler was used in nearly all the repairs to brick pavement in Cleveland in 1911. In selecting a pavement, or any feature of it, it is foolhardy not to take into consideration the openings which must be made in practically all pavements during their probable life.

D. E. McComb, M. Am. Soc. C. E.—The speaker desires to call attention to the difficulty of using grout filler successfully in pavements adjacent to street railways, as the operation of the cars prevents the proper setting of the grout joints near the rails. Under such conditions, in constructing granite and scoria block pavements, the speaker uses a soft filler for a width of ½ in. from the rail, and a grout filler for the remainder of the pavement, with an expansion joint of soft filler adjoining the curb. Mr. McComb.

Attention is also invited to the fact that it is more difficult to repair pavements with grout filler than those with soft filler; in addition to the more difficult removal of blocks, it is, in many cases, practically impossible to keep traffic away from the repaired pavement long enough to permit the cement to set properly.

W. A. Howell, M. Am. Soc. C. E.—In Newark, N. J., there are about 45 miles of brick pavements which have been constructed from time to time since 1895. The cement grout filler there has been entirely satisfactory. About 2 500 sq. yd. of pavement were laid 10 or 12 years ago with a soft filler which was not a success. For a number of years, owing to political influence and to the objection of a Mr. Howell.

Mr. Howell. number of property owners to the noise, a sand filler was used, but it proved very unsatisfactory. At the present time, the grout filler, with 1½-in. expansion joints along the curbs, is being used. A number of years ago the speaker visited Kalamazoo, Mich., where both the grout and the soft filler were used. The experience there at that time seemed to be in favor of the soft filler. There may be climatic or other reasons for using a soft filler in the Middle West which do not obtain in the Eastern States.

Cities along the Great Lakes, such as Cleveland, and Toledo, Ohio, and Erie, Pa., with very highly satisfactory lake sands at their command, should be able to get better results from cement grouting than is obtained in Newark. Although there are at least eight or ten of the best cements in the United States in this district, the local sand is not at all reliable, and even with the greatest care one can hardly expect to achieve the results attained in the Lake cities with only ordinary attention.

Mr. Crosby. W. W. Crosby, M. Am. Soc. C. E.—A great many brick pavements have been laid in the vicinity of Baltimore, Md., during the last few years. The speaker has had charge of several hundred thousand yards of such work, and practically all of it has been built with a grout filler. He fully appreciates the difficulties encountered in using a cement filler with a brick pavement, but, from his own experience and from his observations of the experience of others in different localities, he thinks that the most satisfactory results are obtained with it, if the work is properly done. The speaker has in mind one street, which he sees nearly every day, which was laid 3 or 4 years ago with a soft filler. While its traffic is extremely light, because there are residences only on one side, the bricks are considerably chipped, and the pavement is quite noisy. It does not give a rumbling noise, but the sharper rattle which results from joints which are open at the surface. The specifications used in Baltimore for brick pavements are practically those of the Manufacturers' Association. At the present time, expansion joints filled with pitch are not used except along the curbs.

BITUMINOUS SURFACES.

Mr. Ellis. Fred. E. Ellis, Esq.*—In order to obtain the best results from the application of a bituminous wearing surface to a water-bound macadam road, it is necessary that the road be prepared so that the bituminous material will adhere to the stone composing the surface. The unsatisfactory results obtained in the surface treatment of highways are not due in most cases to the bituminous material used, but to the character of the road and the manner in which it is prepared to receive the treatment. The speaker believes that a mistake is made

* Manager, Essex Trap Rock and Construction Company.

Mr. Ellis.

by taking it for granted that a water-bound macadam road, constructed in the usual manner with a thin top course of small stone, is a proper surface on which to apply a bituminous coating. It is impractical to sweep the surface so as to make it entirely free from dust without at the same time making depressions where the small stones have been displaced by the broom. This is true where soft stone is used for the top course, and more especially where it is not uniform in character, as is generally the case when field stone is used. A comparatively thin top course composed of small stone is also objectionable for another reason. Vehicles traveling on a bituminous surface which is inclined to be sticky, have a tendency to lift out the small stone and, in some places, to tear up the top course for its full thickness. This causes the small holes so frequently seen in roads treated with a bituminous surface, which make such uncomfortable riding. If the dust or binder, either loose or compact, is not removed from the road previous to the application of the bituminous surface, the latter will push around on the road under traffic, and if it is not picked up by the wheels, it will soon lose its life and leave the dry macadam unprotected. When the macadam surface is exposed, the top course of the road disintegrates very rapidly, and, before the proper authorities are aware of it, the road is worn down to the bottom course.

It has been the experience of the speaker, and of others who have tried it, that if the top course of a water-bound macadam road is constructed of stones which vary in size from $1\frac{1}{4}$ to $2\frac{1}{2}$ in., with a depth of 4 in. after rolling, this layer being thoroughly filled with stone dust and flushed, such a surface will withstand traffic for a long time without raveling or breaking up. This surface can be swept clean without disturbing in any way the stones composing it, because they are large and are firmly embedded. There is also very little danger of the stones being lifted out by the traffic, due to the wheels sticking to the bituminous material. This method of construction is used in France, where most expert road builders and road users concede that the roads are the best in the world. The first expense of resurfacing an old macadam road in this manner will be somewhat greater than by the method ordinarily used. The additional expense, however, would seem to be justified because a great many macadam roads at present are not of sufficient thickness to withstand the heavy automobile truck and tractor traffic which, in a few years, they will be called on to bear.

In designing and constructing a road to receive a surface treatment, just as much care should be used in the selection of the stone and in the rolling and flushing as in the case of a road not to be so treated. The idea that a good road can be built with any and all kinds of stone or gravel, if it is to be constructed with a bituminous surface, is a false one, because the object of such a treatment is not to support the load, but solely to keep the binder in place. The cover

Mr. Ellis. for bituminous materials should be composed of broken stone screenings or gravel which will pass through a screen with a mesh of about the size of the thickness of the bituminous carpet required. This is necessary so that the weight of the traffic will be transmitted to the macadam by the stone composing the cover rather than through the plastic bituminous material itself. If the cover is composed of too fine material, without a mixture of a sufficient quantity of coarser particles, the surface will become rutted, the carpet rolling out very thin where the wheels run and increasing in thickness on each side where the traffic is not heavy. The bituminous material should be applied uniformly and in such quantity as will not cause the material to flow toward the shoulders of the road. This can be done best by a machine which applies the material under pressure. Where the bituminous material is applied in such quantity that it flows toward the shoulders, the surface will be wavy, because that part of the roadway where the flowing occurs will take up more of the covering material than where the flowing does not take place, thus giving a thicker carpet in some places than in others.

These remarks do not refer to the application of the purely dust-laying oils. If they are to be used, the surface should not be swept so as to expose the stone, as by so doing the oil will lubricate the stone and the road will ravel.

Mr. Sharples. P. P. Sharples, Esq.*—The speaker does not think that sufficient attention has been given to the difference in treatment required by the variation in the traffic on roads, and to other conditions. One who has followed the application of the tars and road oils which have been used in the United States during the past 6 or 7 years will have noticed that a product showing excellent results at one place may be a complete failure at another. This fact has often been attributed to differences in the bituminous material. A close study of many failures and many successes has shown, however, that the trouble is not caused by differences in the bituminous material, but by dissimilarity in the traffic and in the condition of the surface treated.

At the present time our knowledge enables us to determine, in many cases, the proper treatment for a road. In many other cases we are not yet prepared to state definitely the best thing to do. Several general principles, however, may be deduced from the large number of experiments in New England. The heavy tars and asphalt oils are suitable, as surface applications, when the traffic is mainly automobiles, and give excellent results. Such, at least, has been the experience on the main State highways in New England. When, however, to the automobile traffic is added a considerable amount of steel tire traffic, the conditions change; and if, as is the case in the centers of towns and in the suburban districts of cities, the steel tire traffic predomi-

* Chief Chemist, Barrett Manufacturing Company, Boston, Mass.

Mr. Sharples.

nates, heavy bituminous surfaces are often failures. During the first rainy period, the steel tire traffic and the horses' calks will probably cut up the surface, let the water into it, emulsify the bitumen, and produce a very disagreeable bituminous mud. It has been the speaker's experience that, for such traffic conditions, the thinnest possible treatments will give the best results. This is true of both tars and oils. The application must be made under proper weather conditions, and the dust, resulting from the traffic and from the bringing on of detritus from outlying and untreated streets, must be carefully removed before the bituminous material is applied. Careful attention should also be given to cleaning the streets after the application. Under these conditions light tars and light oils will be successful under traffic which would ruin thick bituminous coatings.

No general rule can be laid down for the time which should elapse between successive treatments. In the case of bituminous roads, the treatment, no matter what it is, must be renewed or the road patched as soon as there are signs of wear. This is a fact which is not yet realized by many engineers in New England, but the treatment of any bituminous surface must be looked after very closely, in order to insure economical results over a period of, say, 5 or 10 years. In some districts the treatment may last for 1, 2, or 3 years, while on another street in the same town, although the surface may have been prepared equally well for the reception of the bituminous material, the treatment will not last more than 6 or 8 weeks. After the treatment has once been commenced, it is folly to stop further applications and let the road go. The only economy is to continue the treatment and get the cumulative benefit of the applications.

In choosing the bituminous material for a surface which will have to be renewed often, care must be taken to select a material which will allow the application of repeated layers. The speaker has seen a number of roads where the material gave good results on the first treatment, but where further treatments added from year to year have produced a rolling and easily moved surface, due to the formation of a thick, plastic blanket. Where a road is to receive successive applications, it would seem to be important to choose a material which will set up or dry out sufficiently to give good results even after a good many treatments.

Another point in regard to these surface treatments, which has not been brought out, is the grade and shape of the roadway before treatment. The bituminous treatments, in every case, make a more slippery surface than the original bare macadam roadway, and, in planning for a surface treatment, this must be kept in mind. For any road having a bituminous surface, it is very important to reduce the camber or side slope to a minimum. A horse, in slipping, does not mind a forward or backward slip very much, but, if he slips sideways he falls

Mr. Sharples. at once, and this should always be kept in mind in the bituminous surfacing of roadways.

The extensive application of bituminous materials to the surfaces of concrete streets has only come up within the past few years, but exceedingly good results have been obtained by the application of tar products to such surfaces. The tar materials seem to be especially adapted for this purpose, as there is no chemical action between them and the alkali of the cement, and the entire material adheres to the concrete until it is thoroughly worn out. The speaker has seen streets treated in this way, which have lasted for 2 years, even with moderately heavy traffic. At the end of this time the bituminous surface was worn down to a feather edge, but it was perfectly feasible to renew this surface at a small cost, and keep the concrete in good condition indefinitely.

Mr. Richardson. CLIFFORD RICHARDSON, M. AM. SOC. C. E.—It may be of interest to explain why an application of oil to the surface of a macadam road after it has been watered may act better than on a dry road. There is always a slight coating of dust adhering to the surface stone, which prevents adhesion. If, however, the surface is sprinkled before the application of the oil, it converts this dust into a paste. The dust is the detritus of the rock, and, like clay, it is more or less colloidal. The result is that the dust in this condition will emulsify with the oil when the latter is applied to the surface and will mix with it so readily that the bitumen will come in contact with the rock, and, after the evaporation of the water, will adhere perfectly. Clay and water will mix with any kind of asphaltic oil, and with the greatest facility. A great deal of it has been used on roads in Germany for distributing oil as an emulsion. The clay and water are mixed with the oil, put into the watering cart, and sprayed on the road.

Another subject, to which the speaker would like to call attention, is the slipperiness of roads which have been treated with bituminous material. Some 25 or 30 years ago, when sheet-asphalt pavements were first being laid, they were objected to because they were so slippery that horses could not stand on them; even within the last year, the speaker has heard from a city in the State of Washington, where the City Engineer had decided that he would have no more sheet-asphalt pavement because it was too slippery. In the early days of the industry, General Edward Fitzgerald Beale, a great breeder of horses in Washington, D. C., in discussing the subject with the speaker, said:

"That is due to the fact that the driver moving over a smooth surface does not drive with the same care as he would if he were moving over a rough surface, and it is also due to the fact that the horse has not learned to travel on that type of surface."

The speaker believes the latter is the better reason. In a certain section of New York State, one of the first bituminous roads, built some years ago, had rather too high a crown, and at first great objection to the character of the road was expressed by all the farmers in the neighborhood, because of its slipperiness in cold weather. Recently, the speaker happened to be in that locality, and asked persons living there what they thought of the road now. They said they had no objection to it; it was a perfect road. This would seem to show that it is a question of experience on the part of the horse and the driver as to how slippery a road may be. Mr. Richardson.

HAROLD PARKER, M. AM. SOC. C. E.—Six or seven years ago, a concrete road about a mile in length was constructed with a bituminous surface of tar. That surface wore fairly well until two years ago; at that time it was treated with Tarvia, and is now in as good condition as when renewed. Mr. Parker.

W. W. CROSBY, M. AM. SOC. C. E.—The speaker is very much interested as to the effect of water in the application of asphaltic oils to roads. Some bituminous materials which he has used for surface treatments have caused a disagreeable mud in the wet season. This mud seems to be due to the formation of an emulsion of the oil and water by the aid of the fine material, such as the finely divided clay, from the shoulders or from cross roads, brought on the treated road. Mr. Crosby.

Some years ago, the speaker used considerable light oil for surface treatment, with the result that, in almost every case, the disagreeable mud complained of occurred during wet weather. Slight differences in the quantity or character of the mud led him to believe that possibly its formation was effected, not only by the traffic, but also by the character of the soil adjacent to the road in question. Consequently, he has been experimenting for a year or two along these lines, believing that light oils may give good results under favorable conditions. For instance, in these experiments, he has used, in both sandy and clayey localities, and under varying amounts of traffic, oils which have proved unsatisfactory elsewhere from the resulting muddiness. From the results of these experiments, he hopes to be able, in the near future, to prescribe limits, both as to traffic and clayiness of the adjacent soil, within which these as yet unsatisfactory materials may be used successfully.

The speaker cannot forbear to call attention again to the importance of recognizing the problem of each road as an individual one requiring particular, as well as careful, consideration for its solution.

The adhesion of a bituminous material to a stone or concrete surface may be increased by the use of a pressure distributor. The pressure machine seems to act like the cement gun when used on dirty steel, because the sand blown through the gun against the steel

Mr. Crosby. cleans off the dirt and allows a good adhesion of the cement. In the same way, the pressure distributor seems to obliterate the dust film between the stone or concrete and the pitch, which nullifies the adhesiveness of the latter; at least, where it has often been difficult to obtain adhesiveness under a gravity application, the results have been entirely satisfactory where the same materials have been applied under pressure.

Five or six years ago, it occurred to the speaker that a cut-back pitch might have desirable characteristics, and he finally succeeded in getting from the Texas Company a cut-back product made up from an asphaltic cement of fairly hard (between 50 and 100) penetration, cut back with a light naphtha. The material was homogeneous, and thin enough to be applied cold. It was put on a new macadam road in good condition and gave excellent results. Since then, considerable of this product has been used with satisfaction. Recently, a product which resembles this original cut-back very closely has been placed on the market. It is capable of cold application, and, while the speaker does not remember all the details of the analysis, he thinks the material lost about 30% at 105° cent. in 21 hours. Each of these materials has been applied in quantities of about ½ gal. per sq. yd., and allowed to penetrate as much as possible under traffic conditions before coating with chips. About 40 tons of screenings per mile were used for coating, and in no case has any complaint reached the speaker concerning the "tracking" of the material. The resulting surface retained its elasticity and life for a considerable period. The cost was reasonable, the so-called natural pitch being cheaper than the manufactured cut-back. The latter required not more than 8 or 10 hours to set after the application of chips, while the "natural" article required about 18 hours.

Mr. Johnston. J. A. Johnston, M. Am. Soc. C. E.—In Massachusetts, for three seasons, excellent results have been obtained by spraying bituminous materials with a pressure of not less than 70 lb. per sq. in., and in light coatings of ¼ gal. per sq. yd. With the nozzle used for this purpose, the pressure is not lost, for the bitumen strikes the road with such force that dust, leaves, or scraps are blown ahead of the machine and out of the way of the spray. This high pressure dislodges the dust and fine particles, forcing the bitumen into every crevice and cranny of the road, adhering to, and gripping, the rough surfaces of the stone, resulting in a thorough bond.

It is conceded that gravity applications are not satisfactory, and that pressure is essential. Pressure below 50 lb. will neither dislodge the dust sufficiently to permit of proper penetration and adhesion, nor spray the light coats (of ¼ gal. or less) as uniformly as can be done with the greater force, and it has been the speaker's practice to use not less than 70 lb.

In repairing old macadam roads which were originally surfaced with No. 2 stone (by which is meant, stone from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. in longest dimension), the surface was first scarified, shaped up, and then worked over with a light hand-harrow, or a farmer's weeder (the latter works even better than the harrow). This served to bring the stone to the top and shake the dirt down under it, so that a clear stone surface was obtained. On some of the roads built of soft stone there were sections so badly pulverized that there were no stone fragments to come to the top. Fresh stone was added in such places (but in 5 miles not more than 100 tons of new stone were used). The surface was then lightly rolled (just enough to smooth it out), after which it was sprinkled, and, while still damp, asphaltic oil, with a specific gravity of more than 0.98, and heated to 200° Fahr., was applied in a layer of $\frac{1}{4}$ gal. per sq. yd., with a pressure of not less than 70 lb. per sq. in., and then covered with grit. Two such coatings of bitumen and grit were used, making a total of $\frac{1}{2}$ gal. of oil, and 0.03 cu. yd. of grit per sq. yd. of surface, and the whole was well watered and thoroughly rolled. With this method the oil carpet sticks, does not creep, and does not roll up. When the surface was finished, the outlines of the stone fragments could be seen, but they were all covered, and thoroughly well bonded together with the bitumen, and none of these roads has shown any disintegration. Mr. Johnston.

The speaker believes that, in applying a bituminous surface treatment to a newly built macadam road, it is best to scarify the surface, as previously detailed, but, if stone of large size (from $1\frac{1}{2}$ to $2\frac{1}{2}$ in. in longest dimensions) is used on the surface, it may be possible to sweep the road so clean that, without scarifying, a good adhesion or bond can be secured.

Ordinarily, it is good engineering practice to build structures which are so substantial that the depreciation and the maintenance cost are reduced, but, if the construction cost is made too large, the interest charge will be so great that it will more than offset the saving in maintenance.

To illustrate this: some time ago, an acquaintance asserted that there would be a great saving if all State roads in Massachusetts were surfaced with stone block or brick, because such paving could be laid in a permanent manner on a concrete base for an average of \$3 per sq. yd., and, with the average travel to which the State roads are subjected, it would last 200 years, therefore the annual cost of maintenance would be only $1\frac{1}{2}$ cents per sq. yd., which is much less than that at present.

Of course, the fallacy of this is easily seen: for, to the depreciation charge of $1\frac{1}{2}$ cents must be added the interest on the first cost of \$3 per sq. yd., which at 4% is 12 cents, making the total $13\frac{1}{2}$ cents, even with the impossible assumption that there would be no other maintenance cost.

Mr. Johnston. Now there seems to be no doubt that, on most of the State roads in Massachusetts, water-bound macadam, covered with an oil blanket, can be maintained by applying a light treatment of oil ($\frac{1}{4}$ gal. or less per sq. yd.) every 2 years, and the cost of this, with such small repairs as may be needed each season, averages about 3 cents per sq. yd. per annum.

The construction cost of such a road surface, including the bituminous top, is about 60 cents per sq. yd. The interest on this investment is 2.4 cents, and this, added to the yearly cost of maintenance and depreciation, makes a total of 5.4 cents for bituminized macadam, as compared with $13\frac{1}{2}$ cents, which is an absurdly low estimate for the so-called permanent paving.

This difference of 7 cents looks small when one thinks of a square yard, but in a mile of road 15 ft. wide there are 8 800 of these square yards; this means that the yearly cost of the paving would be not less than \$1 188 per mile, as compared with \$475 per mile for the bituminized macadam. Moreover, the lower cost surface is dustless, noiseless, and has many desirable features which make for the comfort of the traveler and are entirely lacking in the stone block or brick road.

If proper methods are used in maintaining and resurfacing the bituminous coating, there need be practically no inconvenience to the traffic, for it is perfectly feasible to bituminize more than a mile of such a road in a day, and, in doing this, one side of the road can be kept open for travel.

Stone block, brick, and many other forms of paving, have their legitimate uses, but, in specifying the material or method for surfacing a road, the interest item must not be disregarded.

Mr. Owen. JAMES OWEN, M. AM. SOC. C. E.—Sometimes things are discovered accidently and sometimes by afterthought. There seems to be a great deal of discussion as to whether a road should be cleaned or whether the bituminous material should be applied to the natural surface. The following is a rather curious instance: Oil for the repair of a road had been ordered, but its delivery was delayed. In the meantime, the road began to break, and in order to save it from further disintegration, it was covered, according to the usual practice, with a coating of loam. This covering had been worn down by traffic for a couple of days, when the oil arrived, and, contrary to the speaker's orders, was applied. That piece of road is now the best in the whole system. It would appear, therefore, that engineers have not yet sufficient knowledge to be able to predict just what the result of any treatment will be.

The speaker thinks that the formation of the mush on roads treated with oil is due to the fact that the oil-coated dust is too heavy to blow away and too slippery to wash away. The result is that, when

the rains come, a complete and very efficacious emulsion is formed, which is sometimes 2 in. thick. It is difficult to eliminate this condition, and, in the speaker's opinion, about the only way to prevent it is to apply the oil in time for it to disappear before wet weather comes. Mr. Owen.

C. J. BENNETT, ESQ.*—In Hartford, Conn., nearly all surface treatments with heavy asphaltic oils have been failures. The speaker thinks this is due to two things: the preponderance of horse-drawn vehicles on the city streets and the large quantity of clay soil which, in the fall, mixes with the oil and makes an emulsion resulting in a very disagreeable mud. This condition has obtained with the use of any asphalt oil, whether light or heavy, and whether applied under pressure or by gravity. The question in Hartford is whether the benefits from the oil as a dust-layer in the summer will counterbalance the disagreeable features in the fall. A Texas, 65% oil was used on streets with a heavy traffic until the fall with good results. Standard oil, 40%, Texas oil, 35%, and Indian oil, both light and heavy, were also used with similar results. Tarvia B was used on one street for a surface treatment, and though it gave very good results, as far as the preservation of the surface was concerned, it was not a successful dust-layer, and therefore a light oil was afterward applied to the surface. Mr. Bennett.

A. S. BRAINARD, ASSOC. M. AM. SOC. C. E.—The maintenance of the State macadam roads in Connecticut is accomplished by first applying a coat of Glutrin. After this has been allowed to season somewhat, a light coat of asphaltic oil is applied over the surface, which is then covered with sand or light gravel to prevent tracking. Mr. Brainard.

The speaker is not prepared to state with assurance just what satisfaction this method has given, but it is argued by the Highway Commissioner that, by applying the Glutrin to the surface, he protects the road metal from the disastrous effects of the high-speed automobile. This method allows the aggregate to cement of its own natural ability, and, at the same time, protects the road from the lubricating action of the oil when it is applied, which is said to cause the surface to ravel and disintegrate.

In wet weather the roads are apt to mush up, but whether this is due to the quality of the oil used or to the quantity applied, the speaker is not prepared to say. Very little tar or other bituminous material has been used in construction, and only to a very small extent in making repairs.

G. IMMEDIATO, ASSOC. M. AM. SOC. C. E.—The speaker will describe a failure which resulted from using asphaltoiline, at the rate of about ½ gal. per sq. yd., on a street with different grades but Mr. Immediato.

* Superintendent of Streets, Hartford, Conn.

Mr. Immediato. subjected to the same traffic on all sections. The street carries the heaviest traffic in Montclair. On the hillsides, where the water was shed from the surface quickly, this treatment gave very good results; but on the low portions, where the water could not get away as quickly, the surface mushed up. The asphaltoiline was applied hot (175° Fahr.), after the street had been thoroughly cleaned and scraped. As soon as the oil was put on, it was covered with screenings—about 100 lb. per sq. yd. The surface was thoroughly rolled, and the street was closed to traffic for two days. This gave the material a chance to set thoroughly, which it seemed to do on the hillside. On the low portions, however, it did not set, but remained soft until the end of the season. After every rain the mud was 6 or 8 in. deep in some places, and about 6 weeks ago, it was necessary to scrape the street and remove this mud.

On one street the speaker used calcium chloride in the first part of April, and about 5 weeks afterward the surface was oiled with No. 4 Standard Oil, heated to 175° Fahr. This application was covered with a light coat of screenings, and rolled. This treatment was found to be sufficient to allay the dust throughout the whole season, or from 6 to 7 months. The only streets in Montclair, however, which are absolutely mudless were constructed with Tarvia. One street broke up in August, 1910, and was rebuilt in the following spring by the penetration method, a mixture of Tarvia A and Tarvia X being used.

USE OF BITUMINOUS MATERIAL IN PENETRATION AND MIXING METHODS.

Mr. Armstrong. A. F. Armstrong, M. Am. Soc. C. E. (by letter).—The New York State Highway Department built about 1 300 miles of bituminous macadam highways by the penetration method during 1909, 1910, and 1911. General observation of these roads, which have now been open to traffic for periods varying from 1 to nearly 3 years, indicate that they are in good condition, are giving excellent results, and apparently will continue to give satisfaction for some time to come.

There have been some failures, but they have been few. The writer estimates them as less than 1% of the mileage of the highways built. They were due principally to pouring too late in the season; poor workmanship; wet or dirty stone; brittleness in the bituminous material, and poor foundation. A trap rock road is naturally the hardest to bind, and raveling occurs more frequently on those built with this material than on those where other kinds of stone have been used. It is believed to be of the greatest importance that bituminous macadam, made by the penetration method, should be laid early enough in the season, to have traffic over the road for at least 1 month of

Mr. Armstrong.

TABLE 1.—Cost of Bituminous Material and Filler used Therewith, in Place Complete, by the Penetration Method, Season of 1910. Department of Highways, State of New York.

Highway No.	Length treated, in miles.	Width treated, in feet.	Bituminous Material.		Square yards spread.	Average Number of Gallons per Square Yard.		Average Cost per Square Yard.				
			Cost per gallon at road.	Gallons poured.		First pouring.	Second pouring.	Labor.	Materials.	Equipment.	Engineering.	Total.
Residuum Products.—Application Made in One Pouring.												
321........	4.35	16	$0.110	61 278	40 890	1.50	....	$0.035	$0.180	....	$0.004	$0.219
393........	3.58	16	0.090	49 239	33 648	1.46	....	0.041	0.146	....	0.009	0.196
494........	3.12	16	0.095	41 185	30 091	1.37	....	0.031	0.134	....	0.004	0.169
542........	2.38	14	0.090	29 413	19 575	1.50	....	0.058	0.178	....	0.008	0.244
547........	4.70	16	0.079	68 201	44 285	1.54	....	0.044	0.143	....	0.003	0.190
555........	3.08	14	0.110	31 343	25 368	1.24	....	0.047	0.145	....	0.008	0.200
769........	1.76	14	0.070	21 737	14 490	1.50	....	0.041	0.120	....	0.004	0.165
775........	4.42	14	0.090	52 512	36 302	1.45	....	0.037	0.145	....	0.008	0.190
776........	4.59	14	0.077	60 137	37 710	1.60	....	0.045	0.168	....	0.003	0.216
856........	1.13	16	0.095	14 440	10 581	1.77	....	0.022	0.171	....	0.007	0.200
Totals....	33.11	..	......	429 485	292 940	....	....	......	....	....	....	......
Averages.	3.31	15	$0.091	......	......	1.45	....	$0.040	$0.153	....	$0.006	$0.199
Residuum Products.—Application Made in Two Pourings.												
323........	2.44	16	$0.097	31 293	22 931	1.25	0.11	$0.063	$0.160	....	$0.011	$0.234
637........	3.54	14	0.094	45 064	29 063	1.30	0.25	0.067	0.155	....	0.008	0.231
789........	0.85	14	0.110	11 674	6 998	1.35	0.32	0.040	0.183	....	0.009	0.232
821........	4.07	14	0.095	60 607	33 415	1.33	0.49	0.075	0.178	....	0.009	0.262
5002........	1.69	16	0.095	23 353	15 111	1.10	0.44	0.023	0.160	....	0.003	0.186
5010........	1.98	16	0.090	32 718	18 638	1.41	0.34	0.033	0.191	....	0.008	0.232
5011........	1.73	16	0.096	28 748	16 259	1.30	0.47	0.080	0.160	....	0.015	0.265
5012........	2.78	16	0.093	43 041	26 079	1.25	0.40	0.035	0.220	....	0.004	0.259
5016........	2.97	16	0.093	48 289	27 806	1.29	0.44	0.056	0.176	....	0.006	0.238
5017........	2.46	16	0.078	37 608	23 141	1.20	0.43	0.064	0.172	....	0.008	0.244
Totals....	24.51	......	......	362 395	219 441	....	....	....	....	....	....	......
Averages.	2.45	15.4	$0.094	....	....	1.28	0.37	$0.054	$0.176	....	$0.008	$0.238

Mr. Armstrong.

TABLE 1. (*Continued.*)

Highway No.	Length treated, in miles.	Width treated, in feet.	Bituminous Material.		Square yards spread.	Average Number of Gallons per Square Yard.		Average Cost per Square Yard.				
			Cost per gallon at road.	Gallons poured.		First pouring.	Second pouring.	Labor.	Materials.	Equipment.	Engineering.	Total.
Bermudez Asphalt Fluxed.—Application Made in Two Pourings.												
571........	2.32	14	$0.126	38 190	19 016	1.35	0.65	$0.047	$0.277	....	$0.014	$0.334
665........	1.01	12	0.125	12 487	7 094	1.27	0.49	0.061	0.263	....	0.010	0.334
686........	0.57	14	0.127	8 158	4 652	1.17	0.58	0.072	0.276	....	0.023	0.371
762........	4.70	16	0.118	77 507	44 242	1.25	0.50	0.054	0.230	....	0.010	0.294
867........	0.97	16	0.120	15 542	8 890	1.22	0.53	0.023	0.232	....	0.005	0.260
Totals....	9.57	......	......	151 884	83 894	....	....	....	....	....	....	......
Averages.	1.91	14.4	$0.123	....	....	1.25	0.55	$0.051	$0.256	....	$0.012	$0.319

warm weather, so that it may be thoroughly compacted before cold weather arrives to harden the bituminous material. Mr. Armstrong.

During the season of 1910 cost data reports were received from a large number of roads. These were examined, and computations and tabulations were made from a few of them, the highways selected being those rendering the best and most complete reports. The figures merely show the cost of completing the macadamized portion of the road, after the top stone has been placed and rolled, ready for the bituminous material and filler. As stated in Table 1, the average cost per square yard was

$0.199 for Residuum products, one pouring;
0.238 " " " two pourings;
0.319 " fluxed Bermudez products, two pourings.

Though some of the figures in Table 1 are evidently in error, especially those showing prices of material, the errors are not large. In many cases they will compensate each other, and will not affect materially the average cost. Furthermore, as these figures represent the cost under somewhat varying conditions, for work done in different parts of the State, by different engineers and contractors, on approximately 70 miles of highway, it is believed that they are of more value, for determining the cost of roads of this type, than those obtained from a short-time observation on a single piece of work.

E. H. THOMES, M. AM. SOC. C. E.—As the mineral aggregate constitutes about 90% of a bituminous pavement, it merits more consideration than it generally receives. There is considerable diversity of opinion among engineers as to the proper character and size of the mineral particles which should be used for paving purposes. Before any agreement can be reached it is necessary to be familiar with the materials available, the conditions attending their production, transportation and use, with the practical commercial limitations thereof, and also to designate the size by a uniform method, or to describe it definitely. Mr. Thomes.

At present the size of the mineral matter is specified by the following methods: by the minimum and maximum dimensions of length; by average dimensions, or by diameter, which may mean several things; by passing through a ring or gauge, with or without stating the direction as every or one direction; by passing through or over a screen, with or without stating round or square opening; by passing screens with a definite number of openings or meshes, without stating the gauge of the wire; by passing over holes of a certain size in a revolving cylindrical screen and through holes of another size.

The size is designated, for instance, as ¾-in. stone, ¾ in. in size, ¾-in. gauge, or ¾ in. in diameter. Such a designation may mean the minimum, the maximum, or the average dimension, or the average diameter of the circular openings in the screens used, or it may refer

Mr. Thomes. to the diameter of the ring or gauge through which the stone must pass. Crushed stone passing through the ¾-in. circular perforations of a revolving stone screen will average smaller than that which will pass through a ring of ¾ in. internal diameter, as tested by hand, but it will be larger than the pieces which will pass a ¾-in. ring in every direction. In a revolving stone screen some pieces which would pass through a ¾-in. ring are carried over the moving ¾-in. perforation and deposited with stone of the next larger size. In the vicinity of New York City, commercial ¾-in. stone has been designated by one company as that passing over the ½-in. circular perforations in a rotary screen and through the 1¼-in. openings, and another company designates ¾-in. stone as that passing over the ⅝-in. perforations and through the 1⅛-in. openings. Some designate the first course of bottom stone, which is usually the larger, as No. 1 stone, and some define the small stone which passes through the first perforated section of the screen as No. 1 stone. If stone is specified by dimensions, it is necessary to know the practical limits of production.

Crushed stone may be separated into sizes by fixed inclined screens with various kinds of openings, by shaker screens, or by other devices. Most of the crushed stone used, however, is separated by passing it through revolving cylindrical screens with circular perforations. As it becomes necessary to determine the dimensions of these perforations, it would seem best for the engineer to specify the size of the openings and designate the stone as 1-in. to 2-in. stone or gauge, referring to the diameters of the screen perforations. Unless both diameters of the openings are noted, the size of the stone is indeterminate. Due consideration must be given to the best utilization of all the product of the crusher, because, if only part of the product is used, the price increases. The engineer should inspect the stone plants in his vicinity to familiarize himself with conditions and with the commercial product obtainable. Most quarry men will welcome such inspection, as they are caused much trouble and expense by engineers not having a clear conception of the stone commercially obtainable under their specifications. Proper co-operation between quarry men and engineers will work to the benefit of all. When the engineer controls the entire output of a plant, he can secure any reasonable grading of stone necessary, by the proper length and perforations of the screens, etc.; but, where stone is supplied to a number of consumers from one large plant, it is readily seen that the machinery cannot be changed to suit the whims of each. Special requirements or restrictions and disregard of practical commercial conditions will unnecessarily increase the cost. It becomes necessary to produce a few stock sizes which will best satisfy the demand for various purposes. If the engineers of this Society will agree upon a practicable designation of the sizes of crushed stone and determine standard sizes which will comply with

the best commercial requirements, much trouble and expense can be saved to all parties. Mr. Thomes.

The quantity of dust in stone will depend on the character of the rock, the care in stripping and handling, the quantity of moisture present (as more dust will adhere to stone in wet weather), the velocity and direction of the wind, the type of crusher, the size, length, and condition of the screens, perforations, etc., the distance the stone falls, and the methods used in transportation, construction, rolling, etc. A certain quantity of stone dust may be of advantage in stone for water-bound macadam, or for concrete, if it is uniformly distributed, but, in bituminous pavements, the question of dust and dirt is more important. It is generally specified that the stone for bituminous pavement shall be perfectly dry and free from dust. This is the ideal condition, but it can hardly be attained in practice. As coal-tar products usually penetrate and adhere to dusty stone more readily than asphaltic products, less dust should be permitted with the latter. The stone may be washed by a water sprinkler after it is rolled in place, but it is a question as to what degree this is advisable for bituminous work. Under some conditions, absence of dust is more important than absence of moisture. Dust and dirt should be defined, and the percentage by weight passing a screen with openings, say, $\frac{1}{100}$ in. square, should be specified.

Stone screens are usually from 3 to 5 ft. in diameter, and from 8 to 30 ft. long. They are set up at an inclination of about 1 to $1\frac{1}{2}$ in. per ft., and operated at a peripheral speed of about 200 ft. per sec. The slower the speed and the flatter the inclination the better the separation and the less the dust, but the output is decreased. The longer the screen the better the separation, but there is more dust and more rounding of the stone. The crushed stone usually passes the dust jacket and from the small holes to the larger ones, and the tailings, rejected at the end of the screen, are re-crushed. All the stone may first be passed through a preliminary scalping screen and then dropped to a final sizing or separating screen. If the stones were passed through separate screens, the large ones could be taken out separately, being removed by the last screen, but such restrictions would increase the cost, and it is necessary to determine the degree of screening advisable.

It is commonly specified that crushed stone shall be cubical in shape. This may be the ideal condition, but it can seldom if ever be obtained in practice, especially with trap rock, which is considered the best for road purposes, as it has no grain, rift, seam, or regular place of fracture, like some rocks, and breaks into shape more like a buckwheat grain, with no two sides parallel or regular. The fracture or shape cannot well be specified as it depends mostly on the character of the rock and to some extent on the methods used, and the

Mr. Thomes size, type, and character of the crusher. The gyratory crusher may produce a more uniform size and shape than the jaw type. Hand-broken and sorted stone is better than a machine product, but is out of the question.

Crushed quarry stone is more uniform and better than field stone, but some field stone is very durable. Stone from the same quarry and apparently of the same texture may vary somewhat in wearing qualities. The durability of, and general satisfaction with, a bituminous pavement depends as much on the character and grading of the mineral aggregate as on the character of the bituminous cement. In some respects, the character of the mineral matter is less important in bituminous than in water-bound macadam. The stone in the latter shows rounding of edges, wear, and movement to some depth below the surface, whereas in bituminous macadam this is not so apparent.

The following is the average of three tests of Hudson River trap rock made by the United States Office of Public Roads:

Name, Diabase (trap rock). Character of material, igneous rock.

Specific gravity	2.95
Weight, in pounds per cubic foot	184
Water absorbed, in pounds per cubic foot	0.30
Percentage of wear	2.5
French coefficient of wear	16.0
Hardness	18.3
Toughness	26
Cementing value	good.

While service tests are the only positive indication of the wearing qualities of a rock, laboratory tests are a valuable guide, and if engineers will have their road metal tested, and will record properly all the local conditions and results, the value and reliability of these tests will increase. The resistance to wear, or the abrasion test, and the toughness, or impact test, are the more important ones, though specific gravity, hardness, absorption, cementing value, crushing strength, and chemical analysis may be of value when considered with the other conditions. Instead of stating indefinitely that the rock shall be hard, tough, and durable, it would be better to specify definite practicable limits, in accordance with the foregoing tests.

The majority of engineers seem to prefer about 1 to 1½-in. stone for the upper course, but some claim that the 2 to 2½-in. stone is better, especially for heavy traffic. A few contend that the 1 to 3-in. gauge is the best size. Theoretically, the last may be the best, because this range of sizes has less total voids if the stones of various sizes can be distributed uniformly in the pavement, but, with a wide range in the sizes of screen perforations, it is practically impossible

Mr. Thomes.

to prevent the large and small stone from segregating when deposited on the road. The large stone will fall to the outside of the pile and the fine fragments will remain in the center, and this will cause unequal wear and holes in the pavement. With a soft stone, a large size may give the best results. Stones of large size may make a more durable road if it is properly constructed, but more care is required in thoroughly packing and rolling. More bituminous binder may be required unless stone chips, sand, or screenings are used to fill the voids partly if a large-sized stone is used, and it is difficult to distribute such materials uniformly. A pavement constructed of large stone is more likely to loosen, pick up, and ravel, it has a rougher and more open surface, wears unevenly, and is difficult to repair. Small stone costs more to crush, and contains more dust and waste, but it is more easily handled, produces a smoother and closer surface, wears more uniformly, requires less binder, and is more readily repaired. Small stone is better for patching. The maximum size of the stone may be about one-half the depth of the stone layer.

Stone may be purchased by the cubic yard or by the ton; if by the cubic yard, a more uniform and cleaner stone is apt to be obtained, as the seller secures a larger volume when the product is separated into a number of uniform sizes. If bought by weight, the stone is more likely to contain dust and dirt. It should be definitely stated, when, where, how, and by whom, the stone shall be measured or weighed, whether at the plant or at point of delivery, whether loose or settled, whether on boat, car, truck, etc., and as to what allowance shall be made for dust, moisture, etc. Screenings will weigh more per cubic yard when dry than when damp, because in the latter condition they swell. The following are approximate weights, in pounds per cubic yard, of Hudson River trap rock measured on scows:

Solid rock	4 970
Run of crusher	2 850
$2\frac{1}{4}$ to $3\frac{1}{4}$-in. perforation, or commercially called $2\frac{1}{2}$-in. stone	2 600
$1\frac{1}{8}$ to $2\frac{1}{4}$-in. perforation, or commercial $1\frac{1}{2}$-in. stone	2 475
$\frac{5}{8}$ to $1\frac{1}{8}$-in. perforation, called $\frac{3}{4}$-in. stone	2 400
Passing a $\frac{5}{8}$-in. perforation, called screenings	2 650

The following specifications for size of stone are submitted for suggestions and criticisms, and as a basis for further discussion:

The product of the rock crusher shall be separated into four grades or sizes by an approved method which will produce stone equal to that obtained in the best commercial practice. The separation shall be done in a rotary stone screen having circular perforations of the following diameters: $\frac{1}{2}$ in., 1 in., 2 in., and 3 in. These grades shall be designated as: screenings, $\frac{1}{2}$ to 1-in. stone, 1 to 2-in. stone, and 2 to 3-in. stone, respectively. Screenings which contain less than 5% by weight

Mr. Thomes. of dust passing an opening $\frac{1}{100}$ in. square shall be designated as stone chips. The engineer may permit a slight variation in the sizes, to suit the commercial materials obtainable. For bituminous pavements built by the penetration method, the 2 to 3-in. stone would be laid in the lower course and chips would be used to fill the voids. The 1 to 2-in. stone would be spread next, followed by the bituminous binder, then the $\frac{1}{2}$ to 1-in. stone and seal coat, which would be covered with chips. For the mixing method, any combination or percentages may be used.

In order that a clear understanding may be had when the size of the mineral aggregate is referred to, it is requested that engineers indicate definitely how the material is actually produced, by stating the dimensions of the screen sections and perforations, or otherwise.

The experimental pavements constructed in the summer of 1911 in the Borough of Queens, New York City, on Hillside Avenue, Jamaica, extend eastward from the New York and Queens County Street Railway for a distance of 2 000 ft. to the Soldiers' Monument at Bergen Avenue. The first 200 ft. was constructed with oil-cement-concrete 4 in. thick. The 1:2:4 concrete was mixed with mineral oil to the extent of 10% of the weight of the cement. The concrete was covered with about $\frac{1}{2}$ in. of lean oil cement mortar. A length of 1 200 ft. was built of bituminous concrete in proportions of 18 gal. of bituminous material to 1 cu. yd. of commercial $\frac{3}{4}$-in. stone, of $\frac{1}{2}$ to $1\frac{1}{4}$-in. gauge, laid and rolled to a compacted depth of 2 in. A $\frac{3}{4}$-gal. seal coat was applied to this surface and covered with stone chips. A length of 600 ft. was built of bituminous macadam by the penetration method. A 3-in. layer of loose stone was treated with $1\frac{1}{2}$ gal. of binder, followed by a coating of stone chips. A $\frac{3}{4}$-gal. seal coat was then applied and covered with stone chips. The foundation was an old macadam road which was scarified and brought up to grade with a $1\frac{1}{2}$-in. layer of new stone. The materials for the first 1 400 ft. were mixed in a Smith hot mixer, No. 11. The bituminous materials were heated in a 375-gal., Stevenson and Leonard, heating kettle, and were applied by a Good Roads distributor and Perfection hand-pouring pots. The speaker was in charge of the work for the Borough of Queens, which furnished the labor, materials, and equipment. The work was constructed under the general direction of a Committee of which Nelson P. Lewis, M. Am. Soc. C. E., is Chairman, and in co-operation with the U. S. Office of Public Roads. A census showed an average daily traffic of 1 600 vehicles, mostly motor vehicles.

The work is divided into the following sections:

Section 1, Station 0 (at railroad) to Station 0 + 97, Standard Oil cement concrete.

Section 2, Station 0 + 97 to 1 + 73, Texas Oil cement concrete. Station 1 + 73 to 1 + 97, old stone and brick pavement left in for a cross-gutter.

Section 3, Station 1 + 97 to 4 + 96, Texaco Macadam Binder, a cut-back oil asphalt, in mix, and Texaco Asphalt 55 special cement for a seal coat. Mr. Thomes.

Section 4, Station 4 + 96 to 8 + 00, Bermudez Road Asphalt, a fluxed native asphalt, in mix and seal coat.

Section 5, Station 8 + 00 to 9 + 50, Tarvia X, a heavy refined coal-tar, in mix and seal coat.

Section 6, Station 9 + 50 to 10 + 98, Tarvia X, in mix, and Texaco Asphalt 55 Special for seal coat.

Section 7, Station 10 + 98 to 13 + 94, Standard Special Binder, a cut-back oil asphalt, in mix and seal coat.

Section 8, Station 13 + 94 to 14 + 75, penetration method, Texaco Road Asphalt first application, and Texaco Asphalt 55 for seal coat.

Section 9, Station 14 + 75 to 15 + 50, penetration method, Texaco Road Asphalt for both applications.

Section 10, Station 15 + 50 to 17 + 00, penetration method, Tarvia X for both applications.

Section 11, Station 17 + 00 to 18 + 50, penetration method, Bermudez Road Asphalt for both applications.

Section 12, Station 18 + 50 to 20 + 00, penetration method, Standard Binder B for both applications.

For a distance of about 50 ft. east of Station 20 the Bureau of Highways laid a sample of Amiesite pavement for which the materials were donated by the Long Island Amiesite Company.

F. C. Pillsbury, M. Am. Soc. C. E.—During the past season, greatly increased knowledge of all bituminous materials and how to use them has been gained. One point, which has been brought out more clearly than others, is the necessity for experienced men on the work where the actual handling of the materials is going on, and the payment of wages and salaries sufficient to provide for the continuous employment of such men, so that they may remain on the work long enough to make real advances. The speaker believes that the use of bituminous or other materials requires especially intelligent supervision and labor, in order to obtain satisfactory results, that such results can be obtained in no other way, and that it takes time to develop the necessary knowledge and skill. Most of this work is done under the direction of State, county, or municipal employees, and this point is mentioned because it is so frequently the custom, in public service, to change these employees, on whom so much depends. The speaker has never heard any one disagree with the statement that the personal factor is of prime importance. If, among engineers, there seems to be an apparent lack of interest where this matter is concerned, it can only be ascribed to professional modesty, and if this modesty prevents an engineer from acting in his own behalf, need it Mr. Pillsbury.

Mr. Pillsbury. prevent some kind of united action by such a body as this Society, which certainly stands for the highest principles, and to which engineers all over the world look for standards in all engineering matters?

Engineers have not yet been able to arrive at an agreement on uniform tests to apply to oils, tars, and asphalts. Certainly, no tests have been furnished which can be used in the field. Usually, it is necessary to depend on the word of the dealer, as to the nature of the material furnished. Tests are made by various departments, but, usually, the results have not become known to those actually directing the work until after the material has been used or partly used. There is a great need for the development of some simple tests, born of a practical knowledge of what certain materials will do, and our engineers and inspectors must be educated in some way to that extent. So little is known in general about the various materials, that tars and asphalts are frequently spoken of as oils, and *vice versa,* by men who have used great quantities of them. Even some of the dealers have trade names for certain materials in certain localities and other names for the same materials at other places. One of the greatest things that engineers can do is to work toward the standardization of bituminous materials and methods, and this matter, the speaker believes, has already been taken up by the Special Committee on Bituminous Materials for Road Construction.

Much advancement has been made in the application and use of bituminous binders, and this has led to a better knowledge of the types of surfaces which should be built, therefore, it seems that there has been a gradual elimination of many of the features and methods, as well as materials, which have been subject for discussion in the past. It is not practical, although it is possible, to build a great many different types of road which will answer certain purposes, and to use many different kinds of materials, which would probably give approximately the same results, but would require a greatly varied knowledge in handling. In the near future, it is probable that, for the average country highway, the types of road to be constructed will be few in number, and will then depend more on the mineral aggregate available than on anything else, excepting, of course, the weight and volume of traffic.

One type of road which has been developed under the speaker's observation is a bituminous macadam constructed as follows:

First: Assuming that the sub-grade and surface are properly drained, on the foundation is first placed a layer (4 in. after rolling) of egg-size broken stone, $1\frac{1}{4}$ to $2\frac{1}{2}$ in. in longest dimensions. This layer is thoroughly bound with stone dust or other suitable material, rolled, and flushed with water until it is practically impervious to the bituminous material.

Second: On this heavy asphaltic oil is evenly distributed, by a pressure distributor, $\frac{3}{4}$ gal. per sq. yd. Mr. Pillsbury.

Third: On the oil a layer of nut-size broken stone, $\frac{1}{2}$ to $1\frac{1}{4}$ in. in longest dimension, which will roll to 2 in. thick, is immediately placed and carefully spread with shovels, the carts containing it being driven along the side of the road. The depth of the stone is regulated by wooden cubes placed on the first course, which is sanded at the points where the cubes are placed, in order to prevent them from sticking to the oil. This nut-size stone is then compacted with a steam roller.

Fourth: On the nut-size stone is distributed under pressure about $\frac{5}{8}$ gal. of the same kind of oil as used before, the application being absolutely perfect in distribution, and the penetration reaching well down into the stone.

Fifth: On the oil is immediately spread fine gravel, gravelly sand, or stone screenings, just sufficient in quantity to fill the surface voids in the nut-size stone, and to take up the thin coating of oil left on the top. This is then thoroughly watered and compacted by the steam roller until there are no signs of movement.

The actual costs of such work to the contractor, on two State roads in Massachusetts built in 1911, has been furnished to the speaker by Mr. D. H. Dickinson, the Resident Engineer, and are as shown in Tables 2 and 3.

The traffic on these roads does not consist of a large volume of heavy horse-drawn vehicles, but probably from 500 to 600 automobiles per day pass over them, except during the winter, and there is also considerable heavy farming and other teaming.

In 1908 a number of experiments in mixing sand, gravel, and broken stone with bituminous materials were conducted. These were continued in 1909, and were carried out with oil and gravel to such an extent that it was possible to make definite comparisons while the work was in progress, and since it has been under traffic. These experiments and the later observations warrant specifications by which such work can be described when the conditions and materials available make its use advisable. Realizing the variation in the gravel which occurs even on any particular piece of work, the speaker has provided opportunity for changing the proportions; when the proportion of sand increases, there should be an increase in the quantity of bituminous material, and *vice versa*. For other reasons which may develop, the quantities may need to be varied in order to obtain correct results. This bituminous mixture may be used in re-surfacing old macadam or old gravel roads, or on gravel, macadam, or other bases in new work, and by improving the bituminous material, comparatively heavy traffic may be sustained. All these variations should be based on experience, if possible. The specifications follow:

Mr. lsbury.

TABLE 2.—ACTUAL COSTS OF BITUMINOUS MACADAM CONSTRUCTED AT NORTH ANDOVER, IN 1911.

Length, 8 107 ft.; area, 13 615 sq. yd.; width, 15 ft.

Broken Stone:			
Bottom course:			
Stone, 2 898 tons, at $1.15		$3 332.70	
Cost of laying, including unloading, teaming, spreading, rolling, binding, etc.		1 637.70	
Total cost for bottom course		$4 970.40	
Cost per square yard	$0.3651		
Broken stone dust used to bind bottom course.			
Top Course:			
Stone, 1 148 tons, at $1.15		$1 320.20	
Cost of laying		686.21	
Total cost for top course		$2 006.41	
Cost per square yard	$0.1473		
Oiling:			
First application, ¾ gal. per sq. yd.			
Cost of oil per square yard	$0.0438		
" " heating per square yard	0.0225		
" " hauling " " "	0.0025		
" " applying " " "	0.0168		
Total cost per square yard	$0.0856		
Second application, ⅝ gal. per sq. yd.			
Cost of oil per square yard	$0.0369		
" " heating per square yard	0.0192		
" " hauling " " "	0.0022		
" " applying " " "	0.0168		
Total cost per square yard	$0.0751		
Sand covering:			
Total cost per square yard	$0.0373		
Cost per square yard for bottom course, broken stone		$0.3651	
" " " " " top " " "		0.1473	
Total			$0.5124
Cost per square yard for first application of oil		$0.0856	
" " " " " second " " "		0.0751	
			0.1607
" " " " " sanding			0.0373
Total			$0.1980
Total cost per square yard for pavement			0.7104

Average length of haul for broken stone, 1 mile.
" " " " " oil, 1 "
" " " " " sand covering 1 " ; sand not screened.
Broken stone trap rock shipped by rail.
Oil delivered in tank cars.
Cost of labor, 22 cents per hour.
" " teams, 55 " " "

BITUMINOUS SURFACING.

On the sub-grade and foundation shall be spread, according to lines and grades to be given by the engineer, the bituminous mixture which will form the wearing surface. It shall consist of sand and gravel or broken stones mixed with asphaltic oil. The sizes of stone and sand, the proportions of the same and of oil, and the method of mixing and placing shall be as described hereinafter.

Thickness.—The bituminous surfacing shall be laid in one course, and, after rolling, shall be 2 in. thick at the center and 2 in. thick at the edges.

Mr. Pillsbury.

TABLE 3.—Actual Costs of Bituminous Macadam Constructed at Tyngsboro, in 1911.

Length, 4 350 ft.; area, 7 250 sq. yd.; width, 15 ft.

Broken stone:		
Bottom course:		
Stone, 1 492.05 tons, at $1.15		$1 715.86
Cost of laying, including unloading, teaming, spreading, rolling, binding, etc.		1 137.00
Total cost for bottom course		$2 852.86
Cost per square yard	$0.3935	
Broken stone dust used to bind bottom course.		
Top course:		
Stone, 612.49 tons, at $1.15		$704.36
Cost of laying		439.50
Total cost for top course		$1 143.86
Cost per square yard	$0.1579	
Oiling:		
First application, ¾ gal. per sq. yd.:		
Cost of oil per square yard	$0.0438	
" " heating " "	0.0301	
" " hauling " "	0.0026	
" " applying " "	0.0160	
Total cost per square yard	$0.0925	
Second application, ⅝ gal. per sq. yd.:		
Cost of oil per square yard	$0.0369	
" " heating " "	0.0252	
" " hauling " "	0.0024	
" " applying " "	0.0160	
Total cost per square yard	$0.0805	
Screened gravel covering:		
Total cost per square yard	$0.0589	
Cost per square yard for bottom course, broken stone	0.3935	
" " " " " top " " "	0.1579	
Total		$0.5511
Cost per square yard for first application of oil	$0.0925	
" " " " " second " " "	0.0805	
" " " " " graveling " " "		$0.1730 0.0589
Total		$0.2319
Total cost per square yard for pavement		0.7833
Average length of haul for broken stone, ¾ mile.		
" " " " " oil ¾ "		
" " " " " screened gravel covering, about 1 mile.		
Broken stone trap rock shipped by rail.		
Oil delivered in tank cars.		
Cost of labor, 22 cents per hour.		
" " teams, 55 " " "		

Width.—The width shall be..

Sand.—The sand shall consist of particles which will pass through a screen with meshes ¼ in. square. It shall contain not more than 5% of clay or loam, and be free from adventitious matter.

Stones.—The gravel or broken stones shall run in size from ¼ to ¾ in., and stones larger than ¾ in. in their longest diameters shall not be used.

Proportions of Stones and Sand.—Not more than 75% nor less than 15% of the mineral aggregate shall consist of stones of sizes as

Mr. Pillsbury. hereinbefore specified, and the proportion of sand as hereinbefore specified shall vary according to the proportion of stone used.

Oil.—The bituminous material shall be according to the specifications for the same.

Heating Stones and Sand.—Mixing.—When the sand and stones have been heated to not less than 180° Fahr., or more, if the Engineer requires it, they shall be mixed with the oil, either by hand or by machinery, and as the Engineer may direct, until all particles of sand and stone are covered with oil.

Before mixing, the stone and sand shall be heated separately, and carefully measured to obtain the correct proportions.

Proportions of Oil and Mineral Aggregate.—Not less than 15 gal. nor more than 20 gal. of oil, as the Engineer may direct, shall be mixed with each cubic yard of gravel or stone and sand.

Heating Oil.—Before mixing with the sand, the oil shall be carefully heated to not less than 200° Fahr., and, at that or such higher temperature as the Engineer may direct, shall be mixed with the sand and stone. No oil shall be used after it has been injured by overheating or burning. The Contractor shall heat the oil in suitable kettles or by steam coils, or in such manner as may be satisfactory to the Engineer.

Spreading.—After being properly prepared, as hereinbefore specified, the mixture shall be hauled to the road and spread before it has cooled to a temperature of less than 100° Fahr.

The mixture shall be dumped on steel dumping platforms, or shoveled directly from the cart into place. As the spreading is done, rakes shall be used to obtain a uniform distribution of stones and sand and an even surface before rolling.

Temperature at Spreading.—No oil and gravel shall be mixed or spread when the temperature of the atmosphere is below 50° Fahr., and not any of this work shall be done after September 30th.

Rolling.—The material, after being spread and raked satisfactorily, shall be at once rolled with a steam roller, care being taken not to push the mixture out of place, but to roll so as to lay it down, compressed to a perfect cross-section, and true to line and grade. During very hot weather the rolling shall be done at night or early in the morning, or postponed until cool enough to roll without pushing out of place and shape.

Time to Elapse Before Use.—No teaming or travel of any kind shall be allowed to pass over the new surface until 24 hours have elapsed after the final rolling, or until the surface has become sufficiently hardened not to be injured by picking up or tracking.

Mr. Blanchard. ARTHUR H. BLANCHARD, M. AM. SOC. C. E.—The introduction during 1911 of low first-cost mixing machines, equipped with suitable attachments for heating the aggregate, will be the cause, without

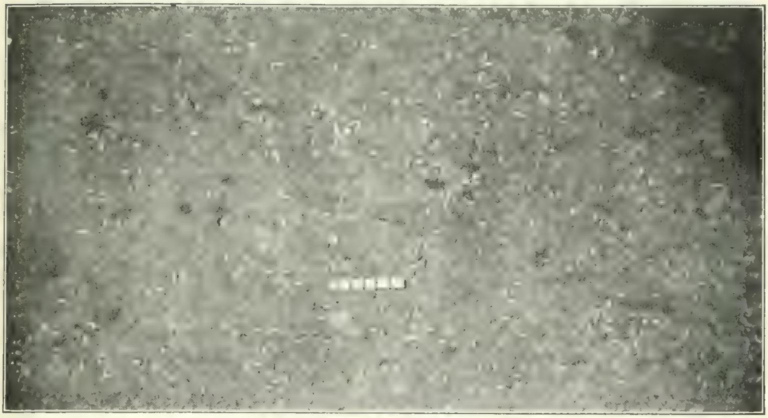


FIG. 1.—SURFACE OF UGITE SECTION.

FIG. 2.—SURFACE OF TARITE, MALDEN SECTION.

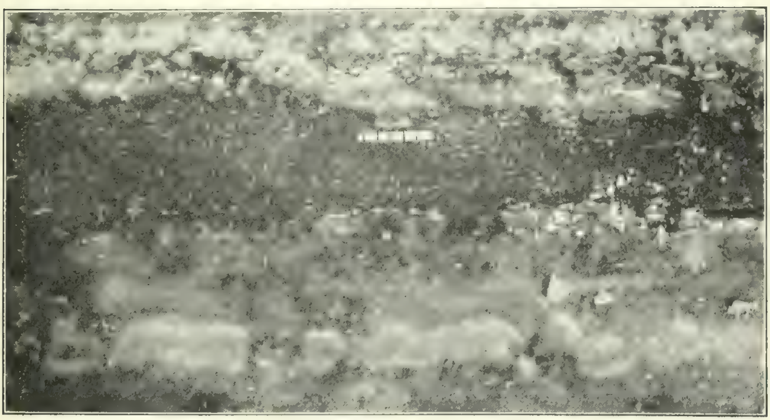


FIG. 3.—SURFACE OF TARITE, ASPHALT 10 PER CENT. SECTION.

Mr. Blanchard.

doubt, of the adoption of the mixing method by many engineers, and of a relative decrease in the use of the penetration method. The time is opportune for the introduction of mixing machines, as the fact is becoming recognized that the average quality of bituminous pavements constructed by the mixing method is decidedly above that of bituminous pavements constructed by penetration methods. This observation pertains to types of bituminous concrete pavements and bituminous macadam pavements in which one-size, crusher-run stone is used in the top or wearing surface.

Bituminous concrete pavements in which broken stone is used may be classified under three heads, dependent on the character of the mineral aggregate:

First.—Aggregates composed of one-size, crusher-run stone;

Second.—Aggregates of one-size, crusher-run stone and sand;

Third.—Finely graded aggregates of stone and sand, with or without the addition of fine mineral matter.

Machines may be purchased for less than $2 000 which will coat satisfactorily an aggregate of the first class with all the different kinds of bituminous materials used during 1911 in work of this class. Although certain aggregates of the second class have been mixed satisfactorily with these machines, the speaker does not wish to make a general statement covering the mixing of all aggregates of this class. More expensive machines have been manufactured, which are economical for mixing aggregates of the second and third types. With efficient machines, the total cost of labor for mixing a 2-in. rolled wearing course should not exceed from 3 to 6 cents per sq. yd.

In many instances fear of injunctions and lawsuits has been responsible for the non-adoption of the mixing method; and it is of interest to note that certain patentees have admitted in writing that the construction of a certain type of bituminous concrete pavement of the first class, composed of one-size, crusher-run stone, is not an infringement of their patent No. 727 505.

In Washington, during 1910 and 1911, there have been constructed, under the direction of the Engineer-Commissioner of the District of Columbia, bituminous concrete pavements having aggregates of the second class. The specification descriptive of the mineral aggregate is: "Trap rock screenings, 2 parts; concrete sand, 1 part; and mineral dust, at least 5% of the above aggregate."

In the cases of Topeka, Kans., and Creston, Iowa, decrees were entered which were agreed to by all interested parties, including the patentees previously referred to, that a certain type of bituminous concrete pavement of the third class is not covered by U. S. Patent No. 727 505. The final decree stated that the composition referred to consisted of stone passing a ½-in. ring, and that less than 10% of the stone and sand should be retained on a screen with openings ¼ in.

Mr. Blanchard. in diameter, and that the pavement could be constructed by the following formula:

Bitumen	from	7 to 11%
Mineral aggregate passing 200-mesh screen,	from	5 " 11 "
" 40 " "	"	18 " 30 "
" 10 " "	"	25 " 55 "
" 8 " "	"	8 " 22 "
" 2 " "	less than	10 "

The speaker has given* detailed descriptions and cost data covering the construction of a series of experimental sections of bituminous concrete pavements which were laid in the fall of 1909 on a section of a State Road in the Town of Barrington, Rhode Island, under his direction while he was Deputy Engineer of the State Board of Public Roads. The condition of the surfaces of the various sections in December, 1910, was also described.

A few facts relative to the condition of these various sections, as observed in January, 1912, will now be presented. It should be noted that all these bituminous concrete pavements were constructed with the same labor, under the same supervision, and by using the same kind of mineral aggregate. The road is at present subjected to a mixed traffic of about 100 horse-drawn vehicles and 250 to 300 motor cars per day. Many of the motor vehicles are of the large touring car type, and travel at high speeds. The experimental sections were constructed to determine the most economical and satisfactory bituminous material to be used both as the cement and for the seal coat for bituminous concrete pavements subjected to trunk highway traffic. Up to January, 1912, no repairs have been considered necessary, and no new material of any kind has been applied to the surface.

The photographs of the surfaces of the various sections show certain characteristics which will be referred to later. It will be noted that a section of a rule 5½ in. in length was photographed on each surface, thus giving some idea of the size of the stones in the surface.

The section built with refined water-gas tar, Ugite No. 4, presented a mosaic surface, well bonded and smooth, which was not slippery, although slipperiness had been characteristic of this section during the winter of 1910-11. Apparently, it will need no repairs during 1912.

The section constructed with a combination of refined coal-tar and 10% asphalt, Tarite-Asphalt 10%, should be treated with a superficial coat of some kind of bituminous material. The surface presented a distinct open mosaic appearance. This surface has not been slippery since it was built.

---

* *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 100.

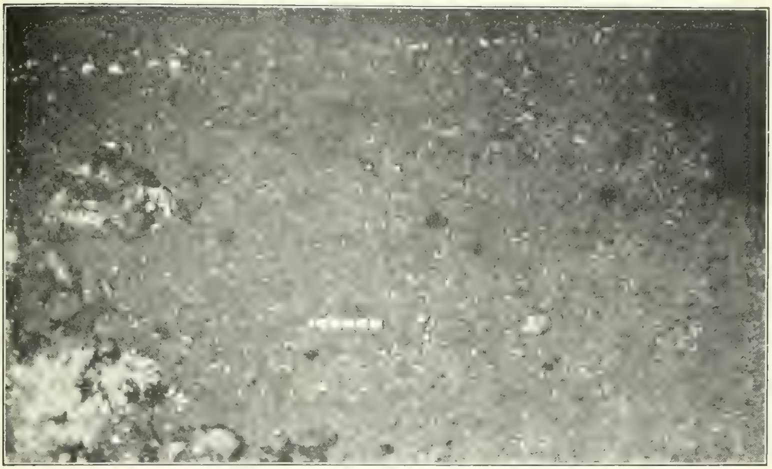


Fig. 1.—Surface of Tarite, Asphalt 20 Per Cent. Section.

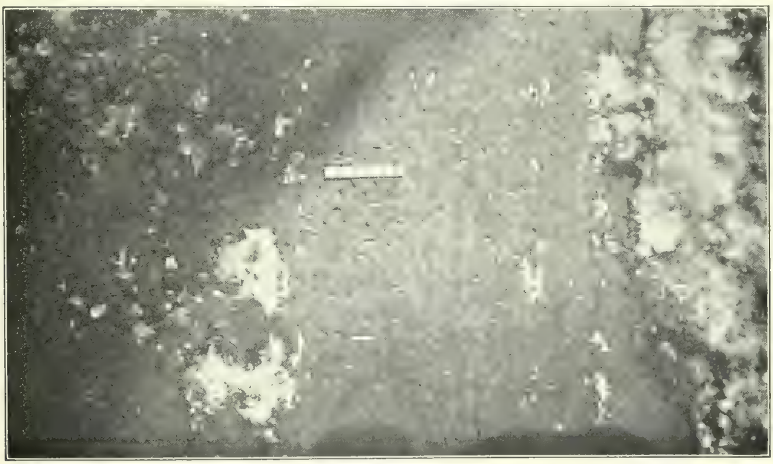


Fig. 2.—Surface of Texaco Macadam Binder Section.

The section built of a combination of refined tar and 20% asphalt, Tarite-Asphalt 20%, had an appearance somewhat similar to that of the section built with refined water-gas tar, and should not require any maintenance during 1912, but will need a superficial coat of bituminous material in 1913. This surface has not been slippery since it was built. Mr. Blanchard.

Both sections built of refined coal-tars, Tarite-Malden and Tarite-Springfield, exhibited an open surface, which, although providing an excellent foothold, will probably disintegrate under a horse-drawn vehicle traffic of 100 to 200 vehicles per day unless properly maintained. Of course, a bituminous surface of tar would increase its life and would be efficacious for from 1 to 2 years, dependent on the development of traffic. Either a tar-asphalt compound or an asphalt would be more effective, and would, without doubt, provide a satisfactory surface for at least 3 years.

The section constructed with Texaco Macadam Binder had a surface similar in appearance to that of a sheet-asphalt pavement. This surface is not slippery. The surface was slightly indented with the horses' calks even with the air temperature at 12° Fahr. Apparently, it will need no maintenance for 2 or 3 years.

It is of interest to note that adjacent sections of the standard type of bituminous concrete pavement adopted for the Rhode Island State Roads in 1909, that is, coal-tar for the mix and a Texaco asphalt, solid at air temperature, for the seal coat, were in excellent condition. They have had no repairs, and apparently will need none during the season of 1912. A photograph of this surface appears similar to that shown for the section where Texaco Macadam Binder was used in the mix and for the seal coat.

W. W. Crosby, M. Am. Soc. C. E.—There has been some question as to the relative values of the different methods, and there seems to be a preponderance of argument in favor of the mixing method and against the penetration method. It seems to the speaker that each engineer will have to be guided in each case by the particular conditions as to which method will be most valuable. Mr. Crosby.

The speaker has never found it necessary to use a seal coat in the penetration work done under his direction. In fact, there have been a number of instances where the absence of a seal coat has been of perceptible advantage, and where there has not yet been any apparent disintegration whatsoever. This result has been secured even when as little as $1\frac{1}{4}$ gal. per sq. yd. of bituminous material has been used. The method of constructing the surface course seems to make no difference as to its need for a seal coat. For instance, in Maryland, the second course may be thoroughly rolled, filled with sand or stone chips, penetrated with the bituminous material, and covered with chips, or it may be built by rolling the second course thoroughly, and applying the bituminous material before putting on any chips

Mr. Crosby. whatever. All penetrated surfaces, whatever material is used, have the tendency to seal themselves eventually. Sometimes the process may be very slow, while at other times it is quite rapid, practically regardless of the quantity of bituminous material used. It has been noticed that where the surface was not filled with chips before the application of the bituminous material, it generally takes longer to acquire a smooth surface than where the chips were used—about a year, perhaps, in the first case, and from 2 to 3 months or less in the second. There is no perceptible difference in the surfaces, however, as soon as a smooth condition is obtained.

TABLE 4.—BITUMINOUS WORK ON

Sect.	Material.	Survey Stations. From:	Survey Stations. To:	Linear feet.	Width, feet.	Locations. Street.	Locations. Station.
1..	Texas	0 — 350	37 + 50	320 65 3 715	30 35 24	Wiley Av. Belvidere Av.	0 37 + 50
2	Gulf Ref. Co.—Asphaltoil. A	37 + 50	44 + 76	726	24	....	....
3..	Texas	44 + 76	49 + 42	466	24	Hayward Av.	46 +
4..	Imp. Prod. Co.—Fairfield	49 + 42	53 + 82	440	24	....	....
5..	U. G. I. No. 4—Sample No. 1.	53 + 82	60 + 24	642	24	....	....
6..	Warren-Puritan Brand No. 10	60 + 24	67 + 09	685	24	Rogers Av.	60 + 75
7..	Tarvia X	67 + 09	74 + 25	716	24	....	....
8..	Amer. Tar Co.—Tarite	74 + 25	81 + 06	681	24	Glen Av.	81 +
9..	U. G. I. (1909 Work)	81 + 06	85 + 45	439	24	....	....
10..	U. G. I. (1910 Work)	85 + 45	97 + 57	1 212	24	Taney Rd.	96 +
11..	Texas	97 + 57	120 + 00	2 243	24	....	....
11 A	Mixed—52 Barrels	120 + 00	124 + 73	473	24	Clark's Lane	121 +
12..	Headley Manf. Co	124 + 73	142 + 30	1 757	24	Belmont Av.	138 +
13..	Barber Asphalt	142 + 30	158 + 06	1 576	24	Seven Mi. L.	150 +
14..	Fairfield—Tar	158 + 06	170 + 00	1 194	24	Slade Av.	170 +
15..	Fairfield—Antidust	170 + 00	199 + 04	2 904	18	Opposite Suburb. Club.	180 +
16..	U. G. I.—Antidust	199 + 04	204 + 54	550	18	Court Rd.	204 +
17..	Sarco	204 + 54	231 + 30	2 676	12	South of Barracks	231 +
18..	Std. Oil—(1910 Work)	231 + 30	245 + 50	1 420	12	Barracks	about 240 +
19..	Std. Oil—(1909 Work)	245 + 50	246 + 32	82	14	....	....
20..	U. G. I	246 + 32	254 + 64	832	14	....	....
21..	Flannigan Texas	254 + 64	259 + 10	446	14	Hooks Lane.	259 +
22..	Gulf Asphaltoil.—A	259 + 10	265 + 38	628	14	....	....
23..	Warren-Puritan Brand No. 17	265 + 38	270 + 81	543	14	Ice Pond.	271 +
24..	U. G. I	270 + 81	285 + 25	1 444	14	Stone Arch Culvert.	285 + 90
25..	Imp. Prod. Co.—Fairfield	285 + 25	295 + 10	985	14	B. Keyser's Entrance.	294
26	Con. G. E. L. & P. Co. complete top of U. G. I	295 + 10	319 + 26	2 416	14	R. R. Bridge.	305 + 25
27	Con. G. E. L. & P. Co	319 + 26 325 +72.5	325 +72.5 326 + 00	846.5 27.5	14 12	S. Side Valley Rd.	326 + 0
28..	Texaco Special	326 + 10	331 + 65	555	12	N. Side Valley Rd.	326 + 10
29..	Glutrin	331 + 65	431 + 92	10 027	12	Coves Rd.	431 + 92

Length, 8.246 + miles.

For the purpose of continuing, for the benefit of those interested, the previously recorded information concerning the work on Park Heights Avenue, Baltimore, Md.,* the writer submits Table 4, which is believed to be largely self-explanatory, and includes the expense on this road to January 1st, 1912. Mr. Crosby.

Attention is called to the fact that Sections 15, 16, 28, and 29, are really surface treatments, and are improperly included perhaps under this topic. On the other hand, to report on them separately might be more objectionable than to include them in this

* *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 74.

PARK HEIGHTS AVENUE, BALTIMORE, MD.

Square yards.	Construction of Macadam per Square Yard.					Maintenance per Square Yard of Macadam.					
	Dates of use.	Gallons used.	Cost of resurfacing.	Cost of pitching, including chipping.	Total first cost.	1910.	Total.	Earthwork.	Painting edges.	Oiling and chipping.	Net actual repairs.
11 226.11	July, Aug., '09	2.39	$0.337	$0.327	$0.664	$0.088	$0.9011	....	....	....	$0.9011*
1 936.00	Aug., Sept., '09.	3.97	0.339	0.434	0.773	0.080	0.0455	$0.0455	....	....	0.0000
1 242.66	Sept., '09.	3.22	0.336	0.418	0.754	0.187	0.9947	....	....	....	0.9947*
1 173.33	Sept., '09.	3.67	0.337	0.449	0.786	0.081	0.0093	0.0093	....	....	0.0000
1 712.00	Sept., '09.	3.12	0.339	0.344	0.683	0.081	0.0506	0.0049	....	$0.0364	0.0093
1 826.66	Sept., Oct., '09.	1.19	0.333	0.606	0.939	0.079	0.0587	6.0024	....	....	0.0563
1 909.33	Oct., '09.	5.40	0.337	0.618	0.955	0.082	0.0268	0.0054	....	0.0180	0.0034
1 816.00	Oct., '09.	4.41	0.336	0.605	0.941	0.080	0.0195	0.0097	....	....	0.0098
1 170.66	Nov., '09.	4.46	0.340	0.454	0.894	0.091	0.0236	0.0187	....	....	0.0049
3 232.00	May, June, 10.	1.43	0.397	0.242	0.639	......	0.0177	0.0097	....	....	0.0080
5 981.33	June, '10.	1.25	0.397	0.264	0.661	......	0.0070	0.0028	....	....	0.0042
1 261.33	June, '10.	1.65	0.397	0.262	0.659	......	0.0353	0.0055	....	....	0.0298
4 685.33	June, July, '10.	1.70	0.397	0.327	0.724	......	0.0378	0.0029	....	....	0.0349
4 202.66	July, Aug., '10.	1.45	0.397	0.325	0.722	......	0.0158	0.0057	$0.0101	....	0.0000
3 184.00	Aug., Sept., '10.	1.69	0.397	0.292	0.689	......	0.0166	0.0048	0.0013	....	0.0105
5 808.00	Oct., '10.	0.61	0.397	0.084	0.481	......	0.0372	0.0037	....	....	0.0335
1 100.00	Sept., Oct., '10.	0.94	0.397	0.140	0.537	......	0.1050	0.0070	....	....	0.0980
3 568.00	Oct., '10.	1.42	0.397	0.325	0.722	......	0.0297	0.0136	0.0161	....	0.0000
1 893.33	Oct., '10.	1.70	0.397	0.287	0.684	......	0.0434	0.0091	0.0281	0.0062	0.0000
127.55	Nov., '09.	3.92	0.241	0.174	0.415	0.087	0.2929	0.0266	....	0.0484	0.2179†
1 294.22	Oct., '09.	3.86	0.230	0.408	0.638	0.088	0.1528	0.0683	....	0.0332	0.0513
693.77	Oct., '09.	4.70	0.228	0.551	0.779	0.088	0.1991	0.0186	....	....	0.1805
976.88	Oct., '09.	2.95	0.229	0.405	0.634	0.082	0.2242	0.0391	....	....	0.1851
844.66	Oct., '09.	4.71	0.224	0.691	0.915	0.082	0.0900	0.0144	....	0.0293	0.0463
2 246.22	Sept., '09.	2.23	0.229	0.257	0.486	0.081	0.0669	0.0114	....	0.0041	0.0514
1 532.22	Sept., '09.	2.73	0.228	0.353	0.581	0.057	0.0854	0.0091	....	....	0.0763
3 758.22	Aug., '09.	2.98	0.216	0.303	0.519	0.057	0.0324	0.0038	....	....	0.0286
1 011.77	Aug., '09.	1.95	0.216	0.227	0.436	0.057	0.0147	0.0088	0.0055	....	0.0004
740.00	Oct., Nov., '10.	1.46	0.369	0.414	0.783	......	0.0232	0.0125	0.0079	....	0.0028
13 369.33	Oct., Nov., '10.	0.56	0.337	0.103	0.440	......	0.0147	0.0139	....	....	0.0308

* Reconstructed, 1911. † Material gratis.

Mr. Crosby. discussion, and, therefore, the speaker hopes that there will be no objection to them, under the circumstances.

Table 5 shows the results of traffic censuses taken at various dates in 1910 and 1911.

Sections 1 and 3 were resurfaced in (August to October, inclusive) 1911, because of their uneven and unsatisfactory surface conditions. The older surface was scarified to a depth of about 3 in., and the mixture of stone and pitch removed. Clean No. 2 trap rock was then spread to a depth of 4 in. (loose), rolled, and poured with 1½ gal. per sq. yd. The stone was then chipped, and a flush coat of ½ gal. per sq. yd. was applied, a final coat of chips being spread on the latter. Section 2 remains somewhat wavy, as was the case a year ago.

Complaints were made that Sections 5, 7, 19, 20, and 23, were slippery in cold weather, and the expense reported on these sections this year is largely that of attempting to overcome this slipperiness. The latter is, in the speaker's judgment, due more to the excess of the pitch originally used, to the grades, and, perhaps, in some cases, to the high crown existing on these sections, than to other factors.

Sections 6, 8, 23, 24, 25, and 26, required the rolling in of additional stone, in order to absorb the excess of pitch appearing in hot weather.

Section 12 bled somewhat during warm weather, and the expense reported on it is largely for overcoming the resulting condition.

Section 15 required patching in numerous small spots (less than 1 sq. ft. in area) during 1911, and the expense therefor is noted. It is now in first-class condition, and, apparently, is likely to remain so, for the present, at least.

Section 16 appears to be losing life, and will probably require extensive re-treatment in 1912.

Section 17 showed a perfect mosaic surface in the spring of 1911, but apparently this mosaic is slowly disappearing by reason of the pitch rising in warm weather and sealing up the surface.

The remarks made in connection with Section 17 will apply to Section 18, except that the action and results referred to were earlier.

Section 19 bled badly in warm weather, and was extremely slippery in cold weather, which accounts for the large expense for putting in extra stone (under "Repairs") and for "Oiling and Chipping."

Section 20 bled somewhat, requiring additional stone, and was slippery enough to require oiling and chipping.

Sections 21 and 22 required the addition and rolling in of considerable stone in 1911. The surface rutted and began to move laterally, but the application of more stone at different times seemed to remedy these defects.

Section 23 was so slippery in cold weather as to require oiling and chipping.

Mr. Crosby.

TABLE 5.—TRAFFIC CENSUS, PARK HEIGHTS AVENUE, 1910–1911, DURING THE PERIOD, 7 A. M. TO 7 P. M.

Class of traffic.	SECTION 1.						SECTION 2.							
	Nov. 14, 1910.		Nov. 17, 1910.		Oct. 19, 1911.		Nov. 15, 1910.		Nov. 18, 1910.		Oct. 14, 1911.		Oct. 21, 1911.	
	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.
One-horse vehicles.	225	450	265	530	263	526	202	404	188	376	211	422	188	376
Two- " "	109	436	99	396	122	488	107	428	94	376	91	376	74	296
Three- " "	10	60	9	54	......	......	3	18	3	18	....	......	....	......
Four- " "	16	128	11	88	2	16	23	184	14	112	2	16	1	8
Six- " "	2	24	....	......	1	12	....	......	2	21	....	......	....	......
Totals	362	1 098	38	1 068	388	1 042	335	1 034	301	906	307	814	263	680
MOTOR TRAFFIC:														
Motor cycles	8	16	8	16	30	60	4	8	5	10	40	80	....	......
Runabouts..........	24	240	27	270	57	570	15	150	14	140	55	550	41	440
Four- or five-seat cars..............	126	2 520	155	3 100	395	7 900	132	2 640	150	3 000	404	8 080	327	6 540
Seven-seat cars....	58	2 320	74	2 960	159	6 360	46	1 840	63	2 520	132	5 280	159	6 360
Omnibuses or drays	2	40	5	100	26	520	7	140	7	140	20	400	32	640
Totals	580	6 234	653	7 514	1 055	16 452	539	5 812	540	6 716	958	15 204	825	14 660

Class of traffic.	SECTIONS 17 TO 21, INCLUSIVE.						SECTIONS 28 AND 29.			
	Nov. 22, 1910.		Nov. 26, 1910.		Oct. 25, 1911.		Jan. 14, 1911.		Jan. 16, 1911.	
	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.	No. movements.	Maryland units.
One-horse vehicles.	26	52	24	48	26	52	10	20	14	28
Two- " "	13	52	8	32	7	28	....	....	1	4
Three- " "	....	......	....	......	1	6	....	....	....	....
Four- " "	....	......	1	8	1	8	4	32	5	40
Six- " "	3	36	2	24	....	......	14	168	11	132
Totals	42	140	35	112	35	94	28	220	31	204
MOTOR TRAFFIC:										
Motor cycles	2	4	5	10	9	18	....	....	....	....
Runabouts..........	5	50	2	20	27	270	....	....	....	....
Four- or five-seat cars..............	33	660	45	900	57	1 140	....	....	....	....
Seven-seat cars....	14	560	23	920	80	3 200	2	80	....	....
Omnibuses or drays	3	60	2	40	4	80	1	20	....	....
Totals	99	1 474	112	2 002	212	4 802	31	320	31	204

Mr. Crosby. Section 28, like Section 15, required some patching of small holes, but not to as great an extent. Between May 15th and July 1st, 1911, more than 1 000 tons of stone were hauled over this section (and Sections 26 and 27) for the construction of a branch road, in addition to the regular traffic shown by the traffic census, Table 5.

Section 29 was treated twice during 1911 by further applications of solutions the same as the original material. These solutions were made of two parts Glutrin and three parts water, and the mixture was applied to the center of the road each time, at the rate of 0.3 gal. per sq. yd.

All sections, except Section 2, are now in first-class condition and, as far as the macadam is concerned, need no repairs.

In Table 4, the column, "Earthwork," shows expense (per square yard of macadam) on shoulders, gutters, etc. The column, "Painting Edges," shows expense per square yard of macadam for this item in those cases where (because the pitch failed to flow out sufficiently to the sides) the edges of the macadam began to deteriorate under traffic. The column, "Oiling and Chipping," shows expense per square yard of macadam for remedying slipperiness by a light coat of cold, thin pitch, followed by a coat of stone chips. The column, "Net Actual Repairs," shows the expense per square yard of macadam for actually repairing the defects.

Mr. Tillson. G. W. TILLSON, M. AM. SOC. C. E.—The speaker hardly agrees with the statement that there is nothing in common in the work of city, State, and town engineers. The papers and discussions presented here are of great value, as they are based on the results of practical experience. If we know why a certain road was a success, or why it was a failure, then certain principles can be deduced which may be applied to the construction of different kinds of roads, and correct results can be obtained.

The Borough of Brooklyn, New York City, has a certain amount of imported rock asphalt pavement. Three or four streets, all in the residential section of the city, were laid with this material in 1895. They cost more than those of Trinidad, California, or Bermudez asphalt, yet the speaker feels that they are better for heavy traffic. As a whole, these pavements have cost less for repairs than those of ordinary asphalt, although they have been down 16 years.

It has been necessary, in making repairs, to use the ordinary sheet-asphalt mixtures, but the speaker believes these repairs have cost less than if they had been made with rock asphalt similar to the original; at least, the unit cost has been less, and the repairs have proven satisfactory.

Mr. Gage. R. B. GAGE, ESQ.*—It is not the speaker's intention to give the origin, theoretical composition, or geographic distribution of that

*Chemist, New Jersey State Road Dept., Trenton, N. J.

large class of organic compounds known under the general term of bitumens, but to consider the use of various compounds in road construction to-day, and state a few of the reasons why they have not always fulfilled the functions expected of them in a satisfactory manner. Mr. Gage.

There are few industries to-day of such magnitude as those of asphalt or coal-tar, which depend so much on chemical reactions and principles, in which the chemistry of the materials used is not better known and does not more definitely control the product than is the case with these two substances. The nature of the ingredients composing them makes a separation of the beneficial from the harmful almost impossible. It is only by making a series of comparative tests, some of which are more physical than chemical, that it is possible to define these mixtures, and even then the operator should have an extended experience, both in the laboratory and in actual construction work, in order to interpret the meaning of the results secured by these tests.

It is this lack of chemical precision or positiveness that makes it so easy, and sometimes convenient, to charge the failure of a bituminous pavement or road to the quality of the bituminous material used. The chemist is expected to make his tests with the utmost care and precision, and is often very severely censured if his results differ slightly from those of another operator. It appears to be taken for granted that a chemist should not make mistakes, that he should produce almost any kind of material that is needed, of an ideal quality, whether such a thing is possible or not, and that he should be censured for all his failures and indirectly for most of the failures of bituminous materials in general. It appears to be human nature to shift the responsibility for a failure to other shoulders than our own, and in this respect there is nothing unnatural about the average contractor or engineer. If a failure occurs, the contractor may not care to admit he has not lived up to the requirements of the specifications, or the engineer may not care to admit that such specifications have not been properly drawn, and therefore the bituminous material is blamed at once as the cause of the failure. However, before passing judgment on the cause of a failure, the chemist's methods will be followed a few steps farther, and the situation analyzed a little more in detail.

In the specifications, great care is generally taken to define the bituminous material and its application. As an extra safeguard, firms supplying such material are often required to give its name, origin, and method of preparation. Apparently, every precaution is taken to secure first-class material, to guard against errors in construction, and to make doubly sure that a first-class pavement will be built. The chemist, from now on, is supposed to check up the

Mr. Gage.

samples of bituminous cements as they are sent to him by the inspector or engineer, for it is very important that this particular ingredient of the pavement be kept up to the requirements as specified. What about the other ingredients of the pavement and conditions which are as important as the quality of the bituminous material, if a first-class pavement is to be produced, and over which the chemist has no control? After the contract has been awarded, the contractor discovers that he can secure some "just as good" material at a lower price than that specified, and he is allowed to use it. Often the bituminous material is improved by the use of some "just as good" flux, or even the bituminous material itself is replaced by a better grade until it is time to take another sample; or, perhaps the contractor cannot afford to wait longer for warm or clear weather, even if his mixtures do get stiff before they can be properly rolled into place. The "run of the crusher" is substituted for the graded sizes of stone specified, that is, half the stone will be coarser than desired and the other half finer. The voids in the former sized stone may be twice as great as in the latter, yet the same quantity of bituminous material per square yard or ton is used. The quantity of dust that screenings shall contain is generally limited in the specifications, but this limit is often forgotten in wet weather, and screenings with an excessive dust content are used. Nevertheless, the bitumen is supposed to digest this excessive quantity of dust when the weather conditions are not favorable for producing clean stone.

These are a few of the details, and it is just as important and necessary that they be kept up to a definite standard, if a good pavement is to be produced, as it is to have a high-grade bituminous material. Neglect in taking proper precautions and maintaining required conditions, which are absolutely necessary to produce a good pavement, has caused more failures than the use of inferior grades of bituminous materials. It is possible with careful manipulation during construction, and good road metal properly graded, to build a fairly good pavement with even an inferior grade of bituminous material; on the other hand, the best of bituminous materials will prove a failure if proper methods of construction are not maintained, and if the mineral aggregate is not kept of the right composition and quality. This failure to keep the methods of construction and the other ingredients of the pavement up to a definite standard of quality is no doubt the chief cause of the pessimistic view many engineers now have regarding the value of chemical tests in determining the quality of a bituminous material. A few years ago many appeared to have the opinion that, no matter how the bituminous material was incorporated into the road, it would perform the functions required of it in a satisfactory manner. A few failures soon proved the absurdity of such views or opinions, and made many very skeptical regarding bituminous roads in general.

Not long ago the speaker listened to an address in which the opinion was expressed that chemical tests were of no value whatever in determining the merits or the qualities of either bituminous or Portland cements, and that the latter never was of much value until its properties were defined by physical tests; also, that the same method of testing should be applied to bituminous pavements, that is, it should be confined to the finished pavement. It is very evident that, in this case, the speaker did not know that all the material used in the manufacture of Portland cement is analyzed first and the mixture is kept as near a definite chemical composition as possible; also, that Portland cement, after it has once taken a set, is practically immune to the action of surface water, while bituminous cements are soon ruined if not protected from these agencies. Almost any bituminous material possesses sufficient strength, when of the proper consistency, to hold the average mineral aggregate together under the worst conditions, provided the life of the material can be maintained. Comparative tests of bituminous and Portland cement mixtures, made to-day, might show high value for the former and low for the latter, but if the same tests are repeated after both materials have been in use for a couple of years, the reverse might be true. During this time the surface waters may have totally disintegrated the bituminous cement but may not have affected the Portland cement in the least. Certain tests may define the quality of Portland cement, yet if used to determine the life of a bituminous pavement, they would be more or less useless, unless accompanied by other tests which would show the ability of these pavements to resist the action of surface waters. Mr. Gage.

There is little doubt that 75% of the failures of bituminous pavements during the last few years, for which the bituminous material has been given the full blame, can be traced to the use of inferior grades of road metal, faulty methods of construction, or combinations of these two causes. In making this statement it is not claimed that all bituminous materials, even when of the proper consistency, are of equal value in road building. Some failures are caused by the use of inferior grades of bituminous material, but these are often used simply because they are cheap, and not because they have been recommended by the engineer or chemist in charge.

Naturally, such failures tend to condemn the use of bituminous materials for similar purposes, and make the securing of contracts for a better and higher priced material often a very difficult task. These failures are frequently explained so nicely, and with such plausible excuses, that they are often repeated in the following year, if the bituminous material used can be shown beyond a doubt to be the best on the market and a great bargain at the price. It is only after the real causes have been correctly interpreted and determined that it is possible to apply the remedies which will prevent a repetition

Mr. Gage. of such mistakes. It may be of financial benefit to certain parties at given times to misrepresent the real cause of these failures, yet this only makes those who are responsible for this particular type of pavement all the more pessimistic, and many times completely kills the chances of similar pavements being again specified. If the chemists or their tests are responsible, the speaker is sure they will gladly shoulder the blame. If the fault lies with the bituminous material, which happens to be of the bargain variety, it is false economy to use it at any price. If the road metal is not of the proper quality or correctly graded, if the methods of construction or preparation of the pavement are faulty, or if the contractor or his men are inexperienced, do not try to shift the blame to the bituminous material or the chemical tests, even if it is very convenient to do so, but place it where it belongs, for only by proceeding in this manner will the real cause of these failures ever be eliminated, and the bituminous pavement be placed in its proper position.

Mr. Dunham. FREDERICK DUNHAM, ESQ.—The speaker has had charge of the construction of bituminous pavements by the penetration method on the Hudson County Boulevard for several years.

In 1907 about 40 000 sq. yd. of bituminous road and an equal area of water-bound macadam road were built in practically the same section for the purpose of ascertaining the difference in the cost, and comparing the life and wearing qualities of the two.

The surface course was composed of 1½-in. stone filled with screenings, which were broomed off before the application of the Tarvia, about ⅔ gal. being used for the first application. This coat was covered with a thin layer of ¾-in. stone and on this was spread the second coat of Tarvia, about ⅓ gal. per sq. yd. This coat was covered with screenings containing about 50% of dust. The water-bound macadam road was of the ordinary type, with 1½-in. stone and screenings in the surface. This road was finished in July, 1907, and was in excellent condition up to about June, 1908, when the heat of the sun caused the surface to wave and roll into bunches. There were no signs of disintegration, however, and the road held together except for the waving, until the spring of 1911, when it was necessary to reconstruct it. When the material was taken up, it showed that, though only 1 gal. per sq. yd. had been used, the Tarvia had penetrated to a depth of about 1½ to 2 in., and still had life in it. The macadam, which was laid at the same time, lasted about 8 months; at the end of that time it had all raveled and gone to pieces. The difference in the cost of the two roads was 10 cents per sq. yd.

In 1908, about 100 000 sq. yd. of bituminous macadam were laid in practically the same manner as in the previous year, except that the quantity of Tarvia in the first application was 1 gal., and in the second application ½ gal. per sq. yd. This road lasted about a year.

Mr. Dunham.

At the expiration of that time, though the surface had not waved much, it had commenced to ravel. Apparently, there had not been enough binder in the second coat. The road disintegrated in places, and had to be repaired at an expense of from 10 to 12 cents per sq. yd.

In 1909 about 100 000 sq. yd. of pavement were laid by exactly the same method as adopted in 1908, except that a better grade of Tarvia was specified. This road was not much more satisfactory than that laid in 1908. The surface had a tendency to creep, and it disintegrated in places, apparently due to unequal distribution of the binder, or because at these points a sufficient quantity of binder had not been used. The bituminous material used in 1908 and 1909 did not seem to hold its life like that used in 1907.

In 1910 about 50 000 sq. yd. of pavement were laid with Tarvia, and about 50 000 sq. yd. with Standard Asphalt Company's Binder A, using $1\frac{1}{2}$ gal. per sq. yd., as before. The work built with Tarvia was in good condition for about one year, possibly 18 months; the road built with Standard Asphalt Binder A is in good condition to-day, and has not needed any repairs. The binder has come to the surface, so that there is no stone visible, and the road looks almost like a sheet-asphalt pavement.

Since 1910, the method of construction has been changed. The first course is composed of $1\frac{1}{2}$-in. stone, and is firmly compacted, the voids being filled tight, as in an ordinary water-bound macadam. On this surface is placed a layer of $1\frac{1}{2}$-in. stone which will be 2 in. thick after rolling. This layer, however, is not filled, as was formerly done. The bituminous material is poured on this course and then covered with $\frac{3}{4}$-in. stone in a sufficient quantity to fill the voids. Another application of bituminous material is made, and the resulting surface is covered with screenings. Standard Asphalt Binder B was used: $1\frac{1}{2}$ gal. for the first application and $\frac{1}{2}$ gal. for the second. This work lasted well for about 6 or 8 months, but after that the $\frac{3}{4}$-in. stone became exposed, and the road looked as if it was about to ravel. A seal coat, using from $\frac{5}{8}$ to $\frac{7}{8}$ gal. per sq. yd., of the Standard Binder A, was applied and covered with about 1 in. of Cow Bay sand. This treatment saved the road, and it is in good condition to-day. On about 45 000 sq. yd. of road 3 gal. of bituminous material were used per sq. yd.; 2 gal. for the first application and 1 gal. for the second. This second coat, however, was covered with dustless screenings or with pea-sized stone in sufficient quantities to take up the asphalt binder. This road looks like a sheet-asphalt pavement, and as if it is going to give very good results.

The best piece of road constructed by the penetration method, up to 1910, was built during the winter. Construction was started on November 1st, but was stopped about the beginning of January on

Mr. [...]nham. account of snow. As soon as the snow disappeared and the road had dried up, work was continued and was finished about March 1st. The bituminous material used was Tarvia X. Naturally, the tar did not penetrate much, and in the spring there was some bleeding. The spots were covered with screenings and rolled, and the road is in as good condition to-day as when it was finished. It does not show the slightest sign of disintegration, but looks like a sheet-asphalt pavement. About December 26th, 1911, 25 000 sq. yd. of road, built by the penetration method, using 3 gal. of binder per sq. yd., were finished. All the work was done in November and December, and, from his past experience, the speaker expects it to be one of the best pieces of road that he has built. Weather conditions, therefore, may not have as much effect on the construction as supposed. The speaker believes that when bituminous material is applied in extremely hot weather, it is likely to penetrate too deep, and that the binder will do more good up near the wearing surface than below. It has been a serious question with him as to whether roads built by the penetration method have many great advantages over ordinary water-bound macadam roads with a surface treatment, though it may be that the cost of maintenance of a road built by the penetration method will be a little less than for resurfacing ordinary water-bound macadam roads.

The penetration method is only a substitute for a bituminous pavement built by the mixing method, and was first used with the idea of economy. Ultimately, the mixing method will have to be used if pavements are to be built to last for any great length of time. If pavements built by the mixing method can be constructed at practically the same cost as those built by the penetration method, as has been stated, there is no doubt that the former method will be by far the most economical.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM PARSONS WATSON, M. Am. Soc. C. E.*

DIED DECEMBER 19TH, 1910.

William Parsons Watson was born at Sycamore, Tenn., on August 1st, 1850. His father, Judge Samuel Watson, moved from Rhode Island to Nashville, Tenn., where, with the du Ponts, he established the Sycamore Powder Mills. His mother was Miss Charlotte Morton, a daughter of Governor Marcus Morton, of Massachusetts.

Mr. Watson was graduated from Yale College in 1869, and after holding various subordinate positions, was appointed, in 1874, Superintendent of the construction and operation of the du Pont and Company's Powder Works, at Sycamore, Tenn., building head and tail races, erecting masonry structures, machinery, etc. He held this position until 1879, when he went to Washington, D. C., where he had charge, for the contractors, of building the B Street Outlet Sewer. In 1880, he was engaged with the United States Coast and Geodetic Survey, in charge of two river and harbor surveys in Maryland and Virginia.

In 1882, Mr. Watson went West, having been appointed Resident Engineer in charge of heavy construction work in the Missouri Cañon, in Montana, for the Northern Pacific Railroad. In 1884, he went to the Canadian Pacific Railway, as Resident Engineer on location, and afterward on construction, in the Gold Range Mountains in British Columbia. He remained with this Company until 1886, when he was engaged on the Montana Central Railway, as Resident and Principal Assistant Engineer in charge of location and construction, for the Great Northern Railway.

From 1888 to 1890, Mr. Watson was employed by the Union Pacific Railway, in charge of the location of its line in Idaho, Montana, and Washington, serving for six months of this time as Chief Engineer on the preliminary surveys of the Portland and Puget Sound Railroad. In 1890, he was appointed Principal Assistant Engineer in charge of the location and construction of the Seattle and Montana Railway, in Washington, completing the work and turning it over to the Operating Department, in 1892.

In 1892, Mr. Watson was employed by the United States Engineer Commission, to make surveys and estimates for a steamboat railway or canal around The Dalles of the Columbia River, in Oregon, which

* Memoir prepared by J. B. Berry, M. Am. Soc. C. E.

position he held until 1893 when he was appointed United States Surveyor General of the State of Washington, remaining in that office until 1897.

In 1898, Mr. Watson returned to the Union Pacific Railroad, having charge of reconnaissance, location surveys, and construction, serving as Chief Engineer of the Columbia Valley Branch and as Principal Assistant Engineer in charge of the Leamington Cut-Off, in Utah. He remained with the Union Pacific Railroad until 1903, when he became Principal Assistant Engineer of the Missouri Pacific Railway, having supervision of its new location and construction work. In 1904, he had charge of the rectification of grades on the St. Joseph and Grand Island Branch of the Union Pacific Railroad.

In 1905, Mr. Watson was appointed Chief Engineer of reconnaissance and location of about 300 miles of a railway line in Southern Indiana, and, in 1906, he was employed by the Chicago, Milwaukee and St. Paul Railway in charge of mountain location and construction in Montana. In 1908, he went to St. Louis, Mo., and entered the office of the Frisco Railway, making investigations and estimates for change of line, reduction of grades, etc. For a year before his death, Mr. Watson was in charge of the investigations for railroad location in the vicinity of Seattle, Wash.

Mr. Watson was competent in all branches of his profession. He was exceedingly painstaking, never neglecting a single item in his investigations, in order that he might give his clients carefully considered conclusions. Being of a cheerful disposition, he was most pleasing in his relations with his associates, readily accepting and investigating any suggestions made by them. If he differed with them, it was always done in a fine spirit. One seldom meets a man so proficient in his work and of such a uniformly fine disposition, so thoroughly loyal, honest, and conscientious.

Mr. Watson was elected a Member of the American Society of Civil Engineers on June 1st, 1887.

INDEX

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS